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Some Potential Sources of Important Plant Products in California

This State offers great facilities for domestic production of many vitally important vegetable products, for the supply of which the United States has heretofore been dependent upon foreign sources. This is particularly true of tannin which can be obtained from native tanbark oak and introduced Australian wattle.

Twelve Authors, Listed in Bibliography

Introduction

In December, 1947, there was held in Los Angeles, California, the Third Annual Conference on the Cultivation of Drug and Associated Economic Plants in California. This one and the preceding two conferences were conducted under the auspices of the California State Department of Education and the California State Polytechnic College of San Luis Obispo. The present article, assembled by the editor of ECONOMIC BOTANY, and approved by Dr. Monroe C. Kidder, the founder and guiding spirit of these conferences, consists of abstracts of, and excerpts from, selected papers presented at the Third Conference. For a number of years since his having founded it, Dr. Kidder has been directing a Drug and Oil Plant Project of the College, the purpose of which is to investigate the possibilities of making American industry independent of foreign sources for these plant products. It is hoped that an early issue of ECONOMIC BOTANY will present to its readers a report on this very worthwhile project. Unfortunately, in June, 1948, the State Legislature of California discontinued the budget that had been supporting this work, but it is hoped that a restoration of the funds will enable the project to continue. The papers from which the abstracts and excerpts have been taken are listed in the bibliography.

Tannin Sources in General

The supply of natural vegetable tannins for American industry is at present not sufficiently assured to make it wise to dismiss the question of their availability lightly. Vegetable tanning materials are utilized in a variety of industries, including the tanning of leather, the treatment of boiler water, mining and the production of dyes. It is in the first of these, the tanning industry, that 95 percent of all vegetable tannins consumed in the United States is used, and this industry, therefore, is the dominant factor in establishing the need for tannins.

About 120,000 tons of 100 percent tannin are used annually in America for such tanning purposes. Three botanical sources furnish almost five-sixths of this amount, and nearly two-thirds of the total is imported. In 1937, 148,942 tons of tannin extract, tan woods and barks, all valued at $7,043,292, were brought in. For the same year domestic production of these materials is reported as having been 244,822 tons valued at $7,800,079. These figures, however, are deceptive for two reasons. In the first place they do not take into account the tannin content of the various extracts; and secondly, imports of raw materials are duplicated as extracts in the figure for domestic production. More accurate statistics for 1939, calculated in terms of

tannin extract containing 25% tannin, and including extract, tan woods, tan bark and other tannin sources, both domestic and imported, are shown in the following table:

MATERIAL	TONS	MATERIAL	TONS
Quebracho	176,500	Spruce	12,000
Chestnut	123,000	Oak	7,000
Mangrove	21,750	Hemlock	4,000
Myrobalans	18,500	Gambier	4,000
Wattle	15,250	Sumac	3,000
Valonia	14,500		

More recent figures for quebracho and wattle, also in terms of tannin extract containing 25% tannin, are:

MATERIAL	1939 TONS	1944 TONS	1945 TONS
Quebracho	176,500	250,801	290,973
Wattle	15,250	37,246	72,677

The significance of the foregoing figures for present purposes is that quebracho is the principal source, chestnut the second, and that utilization of wattle is increasing.

Quebracho is extracted from the wood of the quebracho tree (*Schinopsis Lorentzii*), native to Argentina and Brazil, and all imports of the wood or of extracts come from these two countries. The trees require 125 to 150 years to reach maturity. The wood is extremely hard, containing 20% to 24% tannin by weight; the bark has less. One report says there is enough quebracho wood in South America to meet the demand for 150 years; other reports say the supply will be exhausted in 15 to 20 years. At first glance these statements seem to be completely contradictory, but South American quebracho is becoming more and more remote so far as transportation is concerned; besides, the leather industry in South America is expanding so rapidly that it is probable that very little quebracho will be exported in the postwar years, since South American tanners will consume at least the greater portion of the supply. As transportation costs on quebracho increase, the price of quebracho extract in the American market will rise. Our very extensive use of quebracho at the present time is due to its low cost on the basis of its pure tannin content, rather than to any superiority of this material in leather tannage.

American chestnut wood (*Castanea dentata*) is the second most important source of tannin, and all the material comes from dead trees in the southern Appalachians because chestnut blight prevents natural reproduction and successful planting of this species. The supply of the wood is expected to last only ten or 15 years. Italian chestnut (*C. sativa*), which also furnishes tannin, is being destroyed by a similar disease and will probably soon be extinct.

When we consider that the dominant material, quebracho, is subject to the machinations of an international cartel, that wattle is shunted away from this country because of Empire preference, and that our only domestic source of significant volume today, chestnut, is secured from a vanishing tree whose availability is variously estimated as being sufficient for only 10 or 15 years, then we must admit that a suppply of vegetable tanning materials is not currently assured. We will try to factually present this situation, project it into the future, and try to indicate logical avenues for future productive work.

We may first consider what the supply of vegetable tanning materials was at the start of the recent war, and how the supply situation was displaced by the war. Table I shows a summary of the types of tanning materials employed in this country at the start of the conflict in Europe, and also just subsequent to its spread over the entire world. The 1939 figures are calculated from data obtained from the American Tanning Extract Manufacturers' Association, while the 1942 data are War Production Board

TABLE I

KINDS OF TANNIN, AND THE PERCENTAGES OF THEM, USED IN THE UNITED STATES IN THE YEARS INDICATED

	1939		1942	
	Domestic	Imported	Domestic	Imported
Quebracho	...	44.2	...	45.0
Chestnut wood	30.8	...	27.8	...
Mangrove bark	...	5.4	...	2.9
Myrobalans	...	4.6	...	1.2
Wattle bark	...	3.8	...	5.7
Valonia	...	3.6	...	0.1
Chestnut oak bark	...	...	4.1	...
California oak bark	1.8	...	0.8	...
Hemlock bark	1.0	...	2.8	...
Gambier	...	1.0	...	0.5
Sumac	...	0.8	...	0.2
Divi divi	...	Slight	...	0.3
Tara	...	...	...	0.2
Blends of various materials	...	...	4.7	...
Other	...	...	1.0	...
Sulfite cellulose wastes	3.0	...	2.7	...
Total	36.6	63.4	43.9	56.1

data. Although to a certain extent some of the variation in the data is due to the different sources, it is still true that these data do reflect some of the early shifts in the availability of vegetable tannins in this country.

By 1942 the war in Europe had been in progress for so long that sumac (leaves of *Rhus coriaria*) and valonia (acorn cups of *Quercus Aegilops*) from the Mediterranean area were no longer available in significant quantities, despite the inventory which had been available at the start of the war. Further, the Asiatic war was cutting the availability of materials from the section, as is shown by diminished utilization of mangrove (bark of *Rhizophora Mangle*) and myrobalans (unripe fruits of two Indian trees, *Terminalia chebula* and *T. Bellerica*).

It so happens that as the natural tannins have become more scarce, it has been at the expense mainly of the pyrogallol tannins, and also certain materials especially desired because of the particular properties which they convey either directly or indirectly to leather. It is therefore necessary to increase both the total tonnage of tannin and also the versatility of the available tonnage to permit vegetable tanning control of the leather properties. As we shall discuss later, the possibility of increased production of California tanbark oak extract in greater quantities is highly interesting from both standpoints. While the eventual tonnage is greater from the wattle planting program organized by the Drug and Oil Plant Project, which tonnage will of course be very desirable, a program with better balance for the tanning industry will be represented by the concurrent development of both the tanbark oak and the wattle sources.

The disappearance of customary tannins early in the war was to some extent balanced by greater use of other materials. This shows up in the tabular data in the greater use of chestnut oak wood (*Quercus montana*) and hemlock bark (*Tsuga canadensis*), in the greater significance of materials like divi divi (dried seed pods of Latin American *Caesalpinia coriaria*) and tara (*Caesalpinia tinctoria*), and in the appearance of blends with miscellaneous materials which extract manufacturers were able to prepare, utilizing such casual materials as pecan shells. However, these shifts were inadequate to fill the entire shortage, and especially in the latter phases of the war the availability of different types of tannins became very limited.

Late in the war period only quebracho, chestnut and wattle were available in any significant quantity. The total amount of vegetable tannins employed by the leather industry did not increase drastically during the war. During the five pre-war years (1937-1941) Ameri-

can tanners used about 113,000 tons of 100 percent tannin per year, while during the four war years (1942-1945) they used somewhat over 120,000 tons per year. But we also must consider that for the prewar years the data of the Tariff Commission show that the total utilization of quebracho, chestnut and wattle averaged about 94,000 tons of 100 percent tannin, made up of 49,800 tons of quebracho, 38,700 tons of chestnut and 5,800 tons of wattle. In contrast the War Production Board data for the war years show an average utilization of about 116,000 tons of the three materials. Further, there is an internal shift in that, while the quebracho consumption rose to about 70,000 tons and wattle consumption rose to about 18,000 tons, the consumption of chestnut fell to only 29,000 tons of 100 percent tannin. This fall reflects increasing difficulty in obtaining the wood at some extract plants and, especially, a labor shortage in the forests, both of which lowered extract production.

With the cessation of the war, labor has been somewhat more available, and the extract plants have been able to get additional inventories of wood, but the situation is little if any better than it was. The number of plants extracting chestnut has dropped, and the available wood supply is diminishing.

We have noted that even during the war years chestnut comprised at least one-fourth of the tonnage of vegetable tannins utilized. If this supply should disappear, we would need a replacement tonnage whose size would be almost double the war time losses of tannin sources. We must also not fail to recognize that we thus lose the last significant source of pyrogallol tannin available readily to the American tanner. This is therefore a problem which concerns both the leather industry and our government. An adequate supply of vegetable tanning materials or of some suitable substitute, such as a synthetic material, is necessary if serious dislocations to our entire economy are to be avoided, which dislocations would become especially severe if any future period of international stress should develop.

The prospect for great importation of natural vegetable tanning materials is not especially good. The quebracho supply seems adequate at least for 25 years, and many say for the indefinite future, if present consumption continues and harvesting methods are greatly improved. However, the distribution of quebracho is almost entirely controlled by a cartel which has established export and price controls, so the shortage of tanning materials in this country is exploited to the utmost. World-wide production of wattle is appreciable. However, Australia and South and East Africa are responsible for most of the production. Their own tanning industry utilizes a significant proportion of the wattle production, and Empire preference results in the majority of the export of wattle going to the United Kingdom, while only a minor portion is available to the United States. Wattle production is increasing, and since it is a cultivated woody tree with a maturity period of six to 13 years, its production is subject to considerable expansion. We shall discuss some interesting developments in this country later. However, even though the consumption of wattle in this country is increasing, it is still a poor third in its volume of usage. Further, its South American development is partially controlled by one of the parties to the monopolistic control of quebracho, so that we can not rely too strongly upon its availability.

With the end of the war, some of the lost prewar sources are becoming available again. Further, the war has caused a search of the world for unexploited natural resources which contain tannins.

Latin America has considerable potentialities for development. This is especially true of Brazil where with governmental support production of quebracho and wattle as well as other materials has increased. However, we are still receiving only a limited tonnage from any of these sources. Further, with the war having given a tremendous incentive to industrial development of previously agricultural national economies, it is entirely possible that these redeveloping sources will be used to a large extent for the development of local tanning of leather. Thus it seems wise to discount the value of such developments to the American tannin supply.

It therefore seems evident that the supply picture for vegetable tanning materials in this country is sufficiently precarious to justify some organized effort to improvement. Domestically the disappearance in the not too distant future of chestnut can not be disregarded, while the world supply picture is clouded by monopolistic controls and the development of foreign tanning industry, both of which will work to the disadvantage of the American tanners. The total supply in sight is insufficient, and the available supply is in misbalance as to types of tannin. When we recall the tight supply situation during the recent war, we further see that the development of a factor of safety for any period of future stress is highly advised.

FIG. 1. Dr. Monroe C. Kidder (*left*), Director of the Drug and Oil Plant Project of the California State Polytechnic College at San Luis Obispo, pointing out the rock rose (*Cistus ladaniferus*) to visitors at the trial planting area of the Project, Oceanside, Cal. The leaves and branches of rock rose are rich in oil and resin valued by the perfume industry. The extracts are now imported from Mediterranean countries. (*Photo by Gaylord Johnson, Borrego Springs, Cal.*).

The Drug and Oil Plant Division of the California Polytechnic College has undertaken a very interesting and promising program to increase the availability of vegetable tanning materials from domestic sources. Further, throughout the nation other programs are in progress or have been suggested. There are several possible solutions to the problem:

(*a*) Research work, so that existing sources of tanning materials can be more effectively utilized.

(*b*) Development of synthetic tanning materials.

(*c*) Detection and utilization of existing unused sources of vegetable tannins.

(*d*) Development of cultivated sources of usable materials.

Methods for the better utilization of existing sources of vegetable tanning materials would not add to the total availability of tanning materials especially, but it would serve to make possible better adjustment of the misbalance which currently exists in the types of materials available. During the recent war, since it was so dependent upon imported sources of tannins, the British tanning industry was even more limited than the tanners in America as to types of tanning materials which were available. The shortage of pyrogallol tannins was especially severe, and it became necessary to develop methods of utilizing the available supply of catechol tannins. The British Leather Manufacturers Research Association carried out some research which was followed by plant study that enabled them to utilize wattle as a substitute material for such non-available tanning materials as chestnut. In essence the basis of this development is to be found in the concept that much of the difference in the tanning ability of different extracts is in the varied salt content. Wattle, as an extract of low acidity and salt content and also possessed of good solubility, was found to be especially desirable for modification, in that when the proper additions were made of organic acids and salt, it could be used in the rockers of a sole leather tannery as a replacement for chestnut without the necessity for extensive changes in the customary practice. American shortage of chestnut has not yet become sufficiently severe to result in a concerted effort in this direction here. However, as chestnut becomes more scarce and wattle becomes more available, which is possible, then the American tanners should be able to adopt this proven substitute.

The available supply of tanning materials would of course go further if any portion of the material now discarded as waste could be recovered. Insofar as the tannins themselves are concerned, it does not seem that the wastage is sufficient to be significant, even if it were all recovered. However, associated with the tannins there are non-tannins which are at least in part related to the tannins, but not possessed of all the properties which would make them a tanning material. It has been suggested by some tanners that methods of processing these wastes might add to the total tanning material supply. This is a question which can be answered only after adequate study of the problem. It can not at least be denied that it is a possibility, although it must also be pointed out that it would be a difficult process to justify economically in view of the dilution of these wastes and also the impurities that are present that can not be converted.

In summary we may note that there is a current acute shortage of vegetable tanning materials, and that this shortage could become critical if chestnut should be entirely lost without replacement. It is noted that the synthesis of materials which have similar tanning properties by the American chemical industry is one possible solution to the problem

which is being followed and which offers considerable promise for the future. However, the utilization of untapped sources of vegetable tanning materials or cultivation of tannin-bearing species is another alternative solution which is also promising. The final course of future development will depend upon which alternative can most economically supply the needed tonnage of tanning materials, with the necessary varied characteristics. The program of the Drug and Oil Plant Division to develop tanbark oak and wattle should be very popular regionally. It is also potentially quite significant in that it can give us appreciable sources of two very valuable tanning materials to replace the vanishing chestnut, and its future development will be watched with hope by the American tanner who will be eager to secure any source of a good tanning material at a competitive price.

Tanbark Oak Tannin

The California tanbark oak (*Lithocarpus densiflora*) is a large tree, averaging, in the northern part of the State, 24 inches in diameter at its base and 80 feet in height. There are approximately three million acres of the trees in California and southern Oregon, by far the greatest portion of which is in the first mentioned State. About 20 trees per acre occur in this area. When cut down they quickly sprout from the stumps, and a second cutting is possible at the end of about 20 years.

These trees offer a source of tannin and of wood pulp which so far has only been touched. The tannin derived from them has special characteristics that render it very valuable to the leather industry. It is intermediate in properties between chestnut tannin and the usual oak tannin of commerce, being a depside tannin, so far as the modern classification of tannins is concerned. Formerly it would have been classed as a pyrogallol tannin, since it yields pyrogallol upon destructive distillation. Its practical importance to the leather industry is twofold. In the first place it can replace, at least to a considerable extent, chestnut tannin; and secondly it gives unusual plumping when used for the tannage of sole leather. The bark contains from 18% to 29% tannin, and an average California tanbark oak of the above specified dimensions would yield 509 pounds of dry bark which, assuming an average tannin content of 20%, would provide 102 pounds of pure tannin. This high tannin content of the bark has been recognized for many years, but utilization of the bark as a source of tanning material has been restricted in general to relatively few tanneries on the West Coast, principally in California, and at present there is only one small extract plant, located in Arcata, Calif., available for the production of California tanbark oak extract.

Tan liquors prepared from California tanbark oak penetrate hides at moderate speed, and produce leather of good plumpness and weight, being similar to hemlock and chestnut in this respect. Unless carefully prepared, however, the extract tends to produce leather of slightly redder color than is generally accepted by the trade today, but this color factor can be readily modified.

Dr. E. S. Flinn of the Mead Corporation, Lynchburg, Virginia, advises that a tannin extractor plant must produce commercial tannin extract in a quantity equivalent to 5,000 tons of pure tannin each year in order to make its operations profitable. Since California tanbark oak contains 20 percent tannin, 25,000 tons of this bark would have to be processed annually. This means that the bark from 100,000 California tanbark oak trees would be extracted each year. Inasmuch as there are 20 of these trees per acre in northern California, 5,000 acres per year would be required.

Leaving out of consideration altogether the fact that the California tanbark oak tree grows up again in 20 years from the stump, there are sufficient California tanbark oak trees to keep an extractor plant of this size in operation for the next 600 years. Five thousand acres is only about nine square miles; therefore, a 10 years supply of California tanbark oak for an extractor plant of this capacity would be contained in an area of 90 square miles.

Pulping tests on wood from the California tanbark oak show that the yield of pulp by the sulphate process is 50 percent or a little more. This wood pulp is short-fibred, and in this respect it is inferior to wood pulp obtained from chestnut. It is satisfactory, however, for the manufacture of fine printing and book papers. Modern research has revealed that the addition of two percent synthetic resin to wood pulp makes it possible to manufacture superior wrapping paper and wallboard from short-fibred wood pulps.

It was stated above that 100,000 California tanbark oak trees would be required to produce the 25,000 tons of California tanbark oak needed by a tannin extractor plant. The wood from this number of trees would weigh 311,600,000 pounds, or 155,800 tons. Since a cord of California tanbark oak wood weighs a little less than two tons, this quantity of pulpwood would be equivalent to about 75,000 cords.

Pulp and paper chemists usually figure that 1.5 cords of wood are required to make one ton of paper pulp. The 75,000 cords of California tanbark oak wood would therefore produce 50,000 tons of paper pulp. This estimate is conservative because the wood is especially heavy and because the figure of 1.5 cords per ton of pulp is based on a yield of 40 percent; pulping tests have shown the yield from this native California tree to be 50 percent.

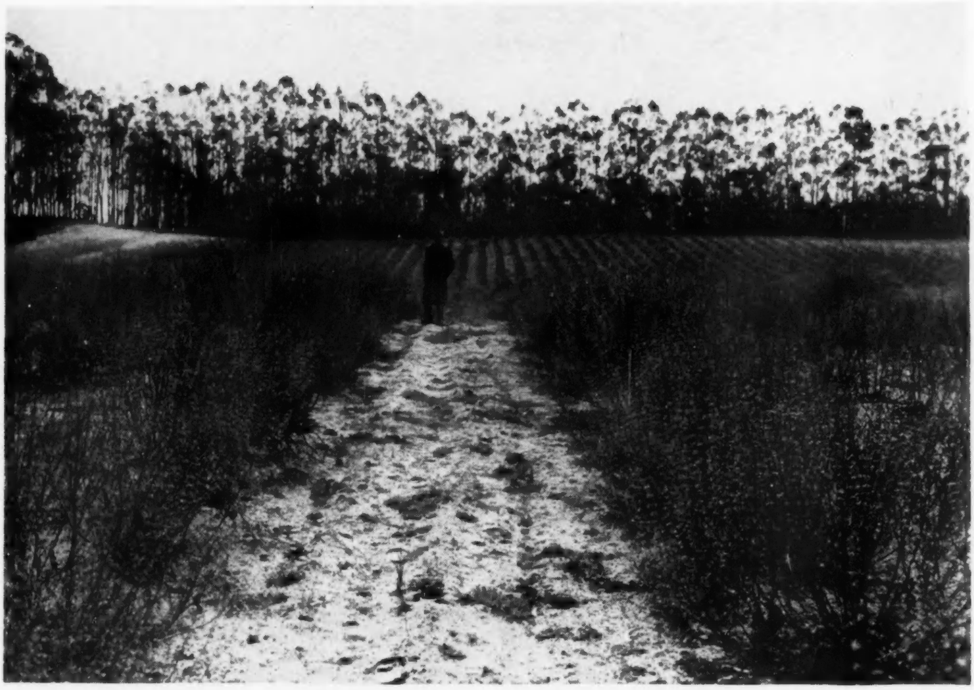
Since there are 250 working days per year, an annual production of 50,000 tons of paper pulp would be a daily production of 200 tons. A pulp mill can operate profitably at such a volume—indeed, a production of 100 tons per day is sufficient.

Since the wood is short fibered and makes a good chemical pulp for book or other fine printing papers, it produces only a mediocre board pulp showing no unusual corrugating properties or high rigidity necessary for this type of product. However, the second growth California tan oak is superior to the virgin growth wood; the first growth wood gives poorer yields and, as a chemical pulp, is more difficult to bleach.

Thus it is apparent that the California tanbark oak can be profitably developed on a commercial scale for the production of a pyrogallol tannin which is so badly needed by the leather industry, and for wood pulp, of which there is a worldwide scarcity with very little relief in sight. This proposed development of the California tanbark oak would add a new economy of $6,000,000 per year to the State of California. Five thousand tons of pure tannin would be worth $1,500,000, and 50,000 tons of paper pulp $4,500,000, if it were sold as newsprint.

Wattle

Tannin-yielding Species. The term "wattle" is applied to arborescent members of the genus *Acacia*, of which genus there are approximately 500 known species. Of these, only three, with their varieties, are of outstanding value as sources of tannin. They are *Acacia decurrens* and its varieties, *A. pycnantha* and *A. penninervis*. There is some confusion concerning the classification of the varieties of *A. decurrens*. According to Dr. J. H. Maiden, formerly Government Botanist and Director of the Botanic Gardens, Sydney, Australia, the foremost authority on acacias, there are



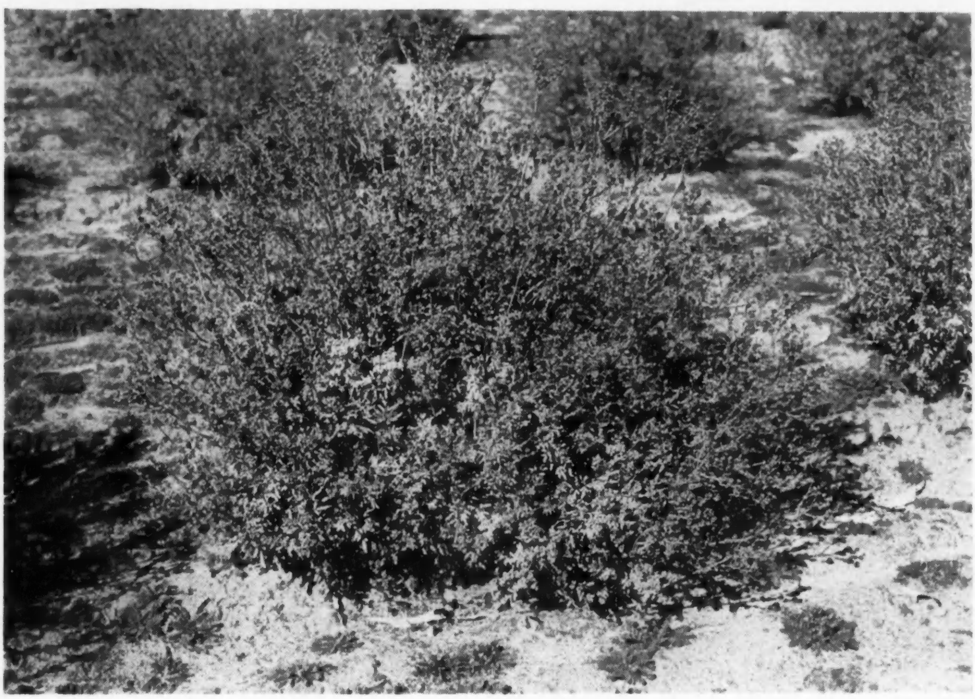


FIG. 2 (*Upper*). A view in 30 acres of pyrethrum (*Chrysanthemum cinerariaefolium*) growing at Arroyo Grande, San Luis Obispo County, Cal. Pyrethrum is an important ingredient of insecticides, and annual imports into the United States before the recent war averaged 15 million pounds, principally from Japan. As a result of the war, production shifted to Kenya, Africa.

FIG. 3 (*Lower*). Close-up of a 50-acre planting of rue (*Ruta graveolens*) in California. These plants, by extraction, are a source of rutin used medicinally to counteract capillary fragility, and, by distillation, of rue oil useful in perfumery. (*Photos by Bob Stratton, Santa Maria, Cal.*).

three varieties of *A. decurrens* interesting as sources of tannin, namely, var. *normalis*, var. *mollis* and var. *dealbata*. Some taxonomists classify var. *mollis* as a separate species, *A. mollissima*, and var. *dealbata* as *A. dealbata*. Dr. Maiden does not feel that these two are separate species, but rather that they are varieties of *A. decurrens*. There are three other varieties of this species, but they are of much less importance so far as tannin is concerned.

Nurserymen in California are confused and inconsistent in the terms that they apply to these trees. They frequently refer to *A. decurrens* var. *mollis* as *A. dealbata*. This error is important because our observations reveal that *A. decurrens* var. *mollis* and var. *normalis* are the two most abundant acacias in California; *A. decurrens* var. *dealbata* is also present, but to a lesser extent.

In Australia, where all these trees are native, and in South Africa, where they have been planted, the term "black wattle" is used to describe *A. decurrens* var. *normalis*; it is sometimes applied also to var. *mollis*, but this latter variety is more frequently called "green wattle". Sometimes, too, *A. penninervis* is spoken of as "black wattle". *A. decurrens* var. *dealbata* is referred to universally as "silver wattle". *A. pycnantha* is "golden wattle".

A. decurrens var. *normalis* and var. *mollis* are very similar, both botanically and in their cultural requirements. Mature specimens of them are from ten to 18 inches in diameter and from 30 to 100 feet tall. Black and green wattles are fast growing and under average conditions reach maturity in ten years, after which time they increase in size slowly and the tannin content of their bark remains constant or decreases. They thrive well on marginal lands and grow even on sandy beaches along the ocean. A well drained and porous soil seems to be essential for them. Too much limestone is detrimental. It is reported that they require a minimum of 16 inches of rainfall per year, and that they survive long periods of drought without irrigation if they receive this amount. Acacia trees in Los Angeles County, however, have prospered without irrigation on as little as eight inches of rain. Moist atmosphere is said to be desirable. On fertile land with more water they grow very rapidly and may reach maturity in seven years instead of ten. Thirteen years may be required where conditions are very unfavorable.

Foreign Production and Use. All of the wattles with barks containing commercially useful quantities of tannin are indigenous to Australia, but in recent years commercial exploitation of these trees has been carried out more extensively in South Africa than anywhere else; indeed Australia now imports sizeable quantities of wattle bark and wattle extract from these regions. South Africa has a climate that is very favorable to wattle culture; in fact the trees do better there than in Australia, and this is probably one of the reasons why South Africa has become the leading country in wattle export. British East Africa, where the trees have also been planted, is not so suitable.

Because they yield the largest amounts of tannin per tree, *A. decurrens* var. *normalis* and var. *mollis* are the only two acacias grown in plantation form in Australia, South Africa and East Africa. The bark of var. *dealbata* contains only one-half to two-thirds as much tannin as does that of var. *normalis* or var. *mollis*. *Mollis* contains somewhat more tannin than *normalis*, but the difference is not great. Bark from *A. pycnantha* contains more tannin than that of any other acacia tree so far investigated. *A. pycnantha*, however, is a much smaller tree so that the amount of tannin produced per tree is less than from the varieties of *A. decurrens*. *A. penninervis*

is a large tree producing thick bark of high tannin content, but this species has received only limited attention as a commercial source of tannin. Var. *normalis* and var. *mollis* grown in Australia produce bark containing 35% tannin; Australian *A. pycnantha* contains approximately 40%. In South Africa both *normalis* and *mollis* are somewhat richer in tannin. In the commercial exploitation of wattle trees in South Africa the bark is converted into a solid extract containing about 63% tannin. This conversion is carried out in a factory near the area in which the trees are cultivated, and is undertaken in order to reduce shipping costs and to eliminate the necessity of processing on the part of tanners.

In recent years wattle culture, based on the varieties *normalis* and *mollis*, has been undertaken on a large scale in Brazil where 30,000 acres are now under cultivation. The trees are on the average only five years old, but enough of them have reached the harvesting stage to convince the Brazilians that wattle culture will be profitable in their country. The plantations in Brazil so far have been made by Brazilian tanners who can use for their own leather production considerably more tannin than will be yielded by the 30,000 acres. They therefore propose to expand their plantings, and there will not be any wattle bark exported from Brazil for some time to come.

Eighty per cent of the world's production of wattle tannin is consumed outside the United States, principally in England, Germany and Australia. One reason for American consumption of only 20% has been an abundant supply so far of tannin from chestnut wood which foreign countries have lacked.

Use and Production in the United States. As already stated, use of wattle bark extract in the United States has been increasing during recent years. In 1939 it ranked fifth as a source of tannin for American leather manufacturers, the amount that year being 15,250 tons calculated to terms of tannin extract containing 25% tannin. In 1945 the quantity increased to 72,677 tons. All of this material, both bark and extract, was imported from South Africa and British East Africa. There is no commercial production at present in the United States, but the already dwindling supply of American chestnut wood and increasing difficulty in obtaining South American quebracho wood make it imperative that we consider cultivation of wattle trees in the United States as a source of tannin.

All the forms of acacia described in the foregoing account were brought to California by the University of California about fifty years ago for experimental study and as ornamentals. They are to be found in our parks and along streets and highways. An abundance of seed is thus readily available, and experiments at the University, carried out between 1900 and 1905, have demonstrated the suitability of California conditions for cultivation of these trees, not only with respect to growth, but also tannin content of the bark.

Plantations of acacia trees require very little care. When the trees are young and before they are ten feet tall, weeding is necessary. After this the shade provided by the trees will discourage growth of weeds. Pruning is largely accomplished by nature. Nevertheless dominant trees must be cut back so that they do not inhibit the growth of surrounding trees. *A. decurrens* var. *normalis* and var. *mollis* are the forms upon which prospective California growers of the trees should concentrate. *A. pycnantha* withstands more heat and drought, and may be better in certain localities. *A. penninervis* should be investigated, although it is a slower grower. Experiments at the University of Cali-

fornia have shown that both *normalis* and *mollis* grown in the State produce bark with a tannin content of 48%; *A. pycnantha* had 46%, *A. decurrens* var. *dealbata* only 24%

If we assume that domestically produced wattle bark can replace our imports of quebracho and 75% of our consumption of domestic chestnut tannin, our total requirements for acacia tannin would be 455,900 tons of extract containing 25% tannin. This estimate is arrived at by adding our consumption of quebracho in 1945 and 75% of our chestnut consumption in 1939 (the latest year for which figures are available) to our use of wattle tannin for the year 1945. It is probable that our consumption of vegetable tannins, including wattle bark, will increase in the future, since the leather industry is expanding.

It will require 325,600 tons of wattle bark to produce the above noted 455,900 tons of extract, and since a mature tree of *A. decurrens* var. *normalis* or var. *mollis* will yield 40 to 50 pounds of bark, 16,280,000 acacia trees must be harvested each year if our potential requirements of wattle tannin, or of tannins that can be advantageously replaced by wattle, are to be met.

Wattle trees should be planted 10′ × 10′, or 435 per acre. This spacing is best because, as proven by experience in Australia, wattle bark contains more tannin when it is protected from direct sunlight. Furthermore, when acacia trees are planted relatively close together they grow taller before branching, and less pruning of lower limbs is required. If this manner of planting is followed, 37,500 acres of acacia plantations must be harvested each year to provide the 455,900 tons of extract. Since an acacia tree reaches maturity in ten years on the average, a total of 375,000 acres must be under cultivation so as to have 37,500 acres maturing each year.

It has been estimated that the annual financial return per acre from a wattle plantation on a ten-year rotation period, the average time required for the trees to attain harvesting maturity, would be about $63; in a seven year rotation, the time required on good land under favorable conditions with plenty of water, the return would be about $90; and on a thirteen year period under unfavorable conditions it would be about $48. These figures take into consideration the value of both tan bark and pulp wood to be obtained from the trees, as well as all costs of production except those of transportation.

In conclusion it should be pointed out to the prospective acacia grower that profit from a venture of this type under our existing tax laws is classed as a long-term capital gain. The maximum rate of tax that can be assessed against such a capital gain is 25%. This alone should be a strong inducement to investment in a project of this character. In view of this, and in view of the handsome profits to be made, and the wealth of experience in Australia, South Africa and Brazil with this type of economy, as well as the experiments by the University of California which have proven the feasibility of growing acacias here, it seems to us that such a development should be undertaken by private individuals on a large scale.

Wattle versus Other Tanning Agents. Wattle bark tannin is superior to quebracho extract in several respects. In the first place, the color of leather tanned with wattle is better than when tanned with quebracho. Secondly, wattle tannin does not precipitate in an acid solution. This is important because all vegetable tanning solutions penetrate hides faster when they are acidified, and leather tanned in an acid solution (pH 3 to 4) has better color than leather tanned in solutions of higher pH. Quebracho tannin is inclined to precipitate out of acid solu-

tions, particularly when salt (sodium chloride) is added to the strongly acid pickle bath in order to diminish the swelling effect of the acidity on the hides. In other words, when pickled hides are tanned, considerable salt and acid are carried over into the tanning solution, and this transfer is quite detrimental when quebracho is used, but not with wattle. If these were the only points of superiority of wattle over quebracho, which they are not, they would be important enough to make replacement of quebracho by wattle worthwhile.

American tanners in the past have not made this replacement because quebracho extract, on the basis of pure tannin contained, has been cheaper and has produced leather with sufficiently good characteristics to meet the ordinary demands of the market. This price situation was quite important in 1940 and earlier, but since then quebracho extract has increased in price more rapidly than wattle extract, and at present the difference between the two is almost negligible. If wattle trees are grown in plantation form in this country, particularly in California, it is more than probable that wattle extract will be cheaper than, or at least will sell at the same price as, quebracho because the price of quebracho is bound to increase as transportation difficulties and demands for local consumption in South America increase, whereas wattle bark, produced here under competitive conditions, will not increase so rapidly, if at all. Wattle culture will be very profitable to both the grower and the processor at the prices now being paid for wattle products.

There is some question as to whether wattle tannin can adequately and completely replace our disappearing chestnut wood extract. Chestnut wood extract is advantageous in the tanning of heavy leathers, such as sole leather and harness. The yield of leather from a given weight of hide is greater when chestnut and mangrove (cutch) are used than when other tannins are employed. Leather is sold by the pound. When tanners speak of yield of leather after tannage, they refer to the weight of finished leather compared to the weight of the raw hide with which they start. The yield of leather is the weight of the hide, plus the weight of tannin fixed by the proteins of the hide during tannage, plus the weight of oil absorbed during fat-liquoring. Hide protein combines with a considerably greater amount of either chestnut or mangrove tannin than is the case with quebracho or wattle tannin. When quebracho extract is treated with sodium bisulphite, this tannin is chemically changed so that more of it will be combined with the protein of the hide, and thus the yield of leather is increased. Perhaps a similar phenomenon would take place if wattle bark were treated in a similar manner with sodium bisulphite, but experimental work in this direction has not been carried out. This problem is one which the laboratory of this Division will attempt to solve.

In 1937 we imported 6,313,078 tons of pulp wood or its equivalent in paper pulp. The actual figures were 1,523,868 cords of pulp wood and 2,394,605 tons of paper pulp. This amount of pulp wood could be supplied by 180,373 acres per year of acacia plantations planted $10' \times 10'$. Since ten years are required for acacias to mature, a total of 1,803,730 acres would be required to replace our imports of pulp wood and paper pulp.

The 375,000 acres of acacia plantations required to provide tannin to replace our imports and our disappearing chestnut represents approximately 30 percent of the acreage required to replace our imports of pulp wood and paper pulp. These computations leave entirely out of account the very important quantity of paper pulp that is now

being produced from chestnut wood. As indicated above, chestnut is rapidly being exhausted, and replacement must be found. If this were taken into consideration, and it has not been for the reason that reliable data are lacking, it is probable that paper pulp from acacia would replace not more than 15 percent of our total imports, that is, on the basis of 375,000 acres, the acreage required for tannin.

It is estimated from data given above and from data from Dr. Maiden of Australia, that each acre of acacia plantation, at maturity, planted $10' \times 10'$ should yield 35 cords of wood for pulping. We believe this estimate to be conservative; it is based on trees ten inches in diameter and 30 feet high; and many acacias will be, after ten years, 18 inches in diameter and 40 or 50 feet high.

Our Division has had pulping tests made on wood from *Acacia decurrens* var. *mollis*. These tests have shown that this wood gives a good yield (52 to 53 percent) of paper pulp suitable after bleaching for book and fine printing papers by the soda as well as the sulphate process. Pulping tests made by the semi-chemical process indicate that wallboard made from acacia would be inferior, owing to lack of strength. This lack of strength is due to the fact that the fibres of acacia wood are extraordinarily short. This short fibre length will not interfere with the value of paper pulp from this wood for book and printing papers. It is possible that paper board made from acacia will have unusual corrugating characteristics or unusual hardness. This has not been definitely established, but, if it is true, it would more than offset the disadvantage of decreased strength. It must be borne in mind, however, that the demand for book and printing papers far exceeds the amount that could be produced from the 375,000 acres proposed above for wattle tannin.

Thirty-seven thousand five hundred acres of acacia plantations, the acreage that must be harvested each year to supply our tannin requirements, will yield annually 1,312,500 cords of 160 cubic feet of acacia wood. The pulping mills in the East are now paying $17 per cord for chestnut wood which gives a lower yield than acacia of paper pulp. Chestnut wood produces better wall board than acacia, but less satisfactory book or printing paper. It is, therefore, conservative to estimate that the value of acacia wood would be the same as that of chestnut wood. On this basis the value of the pulp wood from 37,500 acres of acacia plantations would be $22,312,500. This represents the total addition which acacia wood would make to the economy of the State of California. The total value to our economy of this proposed wattle project would therefore be $38,592,000; that is, the sum of the value of the tannin and the pulp wood produced as a by-product. This does not take into account certain other by-products, for paper pulp is not the only use to which acacia wood can be put. Acacia wood is not satisfactory for the production of lumber in the usual sense of that term. However, it makes excellent mine timbers and good fence posts and railroad ties. It can also be used for making veneer for berry boxes, baskets, *etc.* Wooden boxes made from it are entirely satisfactory. The destructive distillation of acacia wood yields charcoal of good quality as well as methanol, acetone and pyroligneous acid. The quantities and quality of these products compare favorably with those obtained from hard woods and semi-hard woods generally.

The statement has been made that pulping mills utilize only 40 percent of the wood available in the trees they process. It is possible and probable, if the matter is given sufficient study, that the remaining 60 percent can be used

for destructive distillation or otherwise. Our estimate of the amount of acacia wood produced by the proposed acacia plantations is based on the present practice of the pulping industry, and the remaining 60 percent referred to has not been taken into account.

The leaves and twigs of acacia trees upon extraction yield from 12 to 16 percent of tannin. This source of tannim has not been tapped to any appreciable extent commercially because an extract from the leaves and twigs also contains wattle gum, similar to gum arabic, which interferes with the preparation of a solid extract to be used by the tanner. Wattle gum is inferior to gum arabic, but, notwithstanding, it should find a place in the adhesive market at a price at least sufficient to warrant its manufacture. Wattle gum can be separated from an extract of the leaves and twigs by precipitation with alcohol. Since the alcohol could be recovered almost *in toto*, the cost of such processing should be small. The result would be additional tanning extract as well as wattle gum. Surely the last named should bring enough to pay for the processing that its isolation would require, and the value of the additional tannin material would be profit. This additional tannin and wattle gum production has not been taken into account in our estimates of the returns from wattle cultivation in California.

Other Domestic Sources of Tannin

There has also been a significant effort to develop our domestic sources of tanning materials other than tanbark oak which currently have not been utilized. With the spread of industry in this country, and especially with the industrial development in the South, attention has been turned to available sources of naturally growing tannin-bearing species there. Buttonwood (*Conocarpus erectus*) is one source which has been shown to have good tanning properties, including the property of being used effectively to make sole leather. Darling plum (*Reynosia septentrionalis*) represents another possibility. Unfortunately they, like mangrove, are species of the tropical and subtropical areas, especially in Florida, and as such are not too readily available. It is true that tropical areas abroad have been successfully exploited for their tannin-bearing species, but the labor situation is different from that in this country.

Scrub oak is a material not currently utilized to the fullest possible extent. Since oak is a known tannin of appreciable value, development of sources of oak extract would be very welcome to the tanners. The Floridian scrub oak is more accessible than the tropical species, and there seems to be scrub oak available elsewhere in the South. It would appear very desirable to carry the investigation of scrub oak to its logical conclusion and produce a sufficient tonnage of the material to make a tannery evaluation possible.

Three species of American sumac can, if correctly processed, furnish a ground leaf with considerable promise as a tanning material. The best, *Rhus copallina*, or dwarf sumac, produces a material which is evaluated in the tannery as being almost equal to Sicilian sumac (*R. coriaria*), although the leather color is a little dark. Since sumac is one of the tannins that is valued for the special leathering properties it possesses , this domestic source is especially interesting. It must, however, be reiterated that the emphasis must be placed upon careful processing. That domestic sumac possesses tanning potentialities has long been known, but careless harvesting has usually ruined it. Here again, American economics and perhaps climatic conditions have hindered the development of the domestic source.

Hemlock bark represents a known source of vegetable tanning material which has been very inadequately exploited in this country. Table I shows that hemlock bark tannin comprises only a small portion of the total tannin tonnage, yet there is extensive utilization of hemlock by other industries, with the bark being largely wasted. In the Great Lakes area eastern hemlock bark (*Tsuga canadensis*) is discarded in sufficient quantity so that preliminary surveys indicate the justification of the establishment of extract plants. Years ago large quantities of it were utilized by American tanners, and it was used along with oak as the sole tanning materials employed in many tanneries. There seems to be no adequate reason for its decrease in utilization, although the shortage of bark is often given as a reason. In view of the present shortage of tannins and the known wastage of this bark, it is to be hoped that efforts to utilize it will be made.

Western hemlock bark (*Tsuga heterophylla*) is also a waste of tremendous quantity. Its utilization up to this time has been handicapped by the remoteness of the source of bark from the location of vegetable tanning industries in major centers of the eastern section of the United States, and by lumbering practice in its major areas. The logs are floated for appreciable periods in salt water, which lowers the tannin content of the bark and contaminates it. However, the potential tannin from this source is so great that it is tragic to lose it. Since it involves such extensive problems, and since so much hemlock is on government land, it is almost inevitably a project which must receive governmental support. It was considered a war-time possibility and it seems logical to prosecute the issue to its final conclusion now when the imminence of a need for more tannin would encourage such a long term project.

Another West Coast source of tanning materials in appreciable tonnage would be wastage from the redwood (*Sequoia sempervirens*) industry. The Institute of Paper Chemistry has carried out an extensive research study of redwood tannins. The tannery utilization of redwood tannin has progressed to the point that one of the larger extract manufacturers has extracted several tons of the waste and prepared sufficient extract for a tannery evaluation. While the results indicate that there are still problems to be solved in handling this material, they also indicate its potential promise. While its West Coast location may handicap its nation-wide use, it will certainly be available in an appreciable tonnage if it is proven to be desirable enough.

So far we have been discussing the utilization of naturally available sources. It would, of course, also be possible to cultivate tannin-bearing plants if species with sufficiently short cropping periods could be found. In the sense that cultivation might also be considered to include reforestation, any of the tannin-bearing species might be cultivated. Thus it has been suggested that Chinese chestnut (*Castanea mollissima*) would be a blight-resistant replacement for native chestnut, and plantings have been made to study this possibility. It does not seem likely, however, that this possibility will develop. Further, under the present conditions of American economy, projects that are delayed over a period of many years are not likely to be very favorably received. However, in terms of shorter maturity plantings, or even annual harvests, there may be some possibilities for future development.

During the war there was at least one successful utilization of waste from a cultivated species. Pecan shells contain tannin, especially in the form of a powder around the septa, and this powdery material was successfully utilized during the war as a component of a blended extract.

Canaigre (*Rumex hymenosepalum*) is

a dock-like plant whose root is a source of tannin and grows in the arid southwestern United States. At present it is a wild plant, but its cultivation and harvesting over a period of one or two years seems feasible. Development of this material has been carried on for several years by the Eastern Regional Research Laboratory. Preparation of a suitable extract has been handicapped in the past by the presence of a high content of carbohydrate materials including soluble sugars and starch. Hence extracts are of low purity unless special processes are employed. Even though canaigre has been known for 50 years and was used at the start of the present century to make commercial leather, it has not been utilized commercially in recent years. The work of the Eastern Regional Laboratory now offers promise that the difficulties with this material may be overcome.

Synthetic Tannins. The question has been raised as to what possibility exists for replacement of vegetable tanning materials by synthetics.

Prior to the recent war the German chemical industry had been actively engaged in the production of synthetic tanning materials which could replace natural vegetable tannins. Their efforts were so successful that it was possible in some instances to use these materials exclusively and still produce good leather. Many military leathers employed 40 or 50 percent of these materials in the blends used to produce them, and it was obligatory to use a certain percentage of these materials on non-military leathers. The development of replacement synthetics by the American chemical industry did not occur as soon as the German development did. Because of the critical shortage of vegetable tannins, the office of the Quartermaster General over the past several years has been sponsoring a research program directed toward the development of synthetic tanning materials. This program has been coordinated at the Tanners' Council Research Laboratory. Through their early cooperation in this program and through extensive individual research, the Mon-

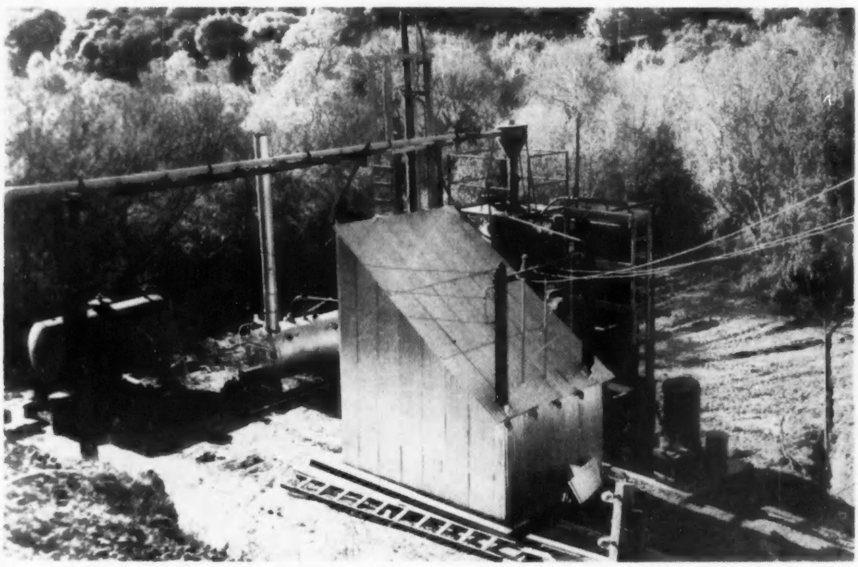


FIG. 4. A distillation plant in Marin County, Cal., for recovery of California bay tree oil from *Umbellularia Californica*. This oil contains umbellulone which is convertible into thymol, medicinally valuable as an antiseptic.

santo Chemical Company has been able to produce synthetic tanning materials which have been shown to be usable with, or in place of, natural vegetable tannins. Other materials of a synthetic nature are also currently being developed, so that the future availability of such materials is promising.

These synthetic materials, however, have one disadvantage which is probably impossible to overcome. Even with the current increase in the cost of natural tanning materials that has resulted from the current shortages, they are not nearly so expensive as the synthetic materials, particularly when these synthetic materials are compared in cost to the dominant three, quebracho, chestnut and wattle. While the synthetic materials are being used, this use is not occurring in the sole leather industry where the cost of the tanning material is a more significant portion of the total leather cost; yet this is the largest branch of the leather industry in the utilization of vegetable tannins. When we consider that the dominant three vegetable tanning materials are currently selling at 12 to 18 cents per pound of 100 percent tannin, and when we further consider that this is the cost range of such raw materials for the synthetic tannins as phenol, cresol, formaldehyde or furfural; then we can readily appreciate the necessarily higher cost of the synthetics. Since, pound for pound, it is not possible to convert the raw materials into tannin substitutes, and since the production cost must be covered, it is readily apparent that the costs of the synthetics will always remain high. It may of course be true that operating economies will lower the cost of the synthetics, and that scarcity of natural tanning materials will force further rises in the cost of these materials, so that the two types of materials will eventually be competitive in cost. This will, however, result in increased cost of leather production.

There are, however, certain alleviating circumstances about this greater cost of the synthetic materials. Presently the available synthetics do not produce equivalent leathers more economically nor do they produce demonstrably superior leathers than is possible with the natural tannins. However, as we learn more about these materials we will learn how to make this true, and particularly the ability to produce superior leathers will be worth some additional cost. Further, these materials will have a uniformity in properties which is not possible with natural materials. There is also the possibility of using these synthetics in conjunction with low grade tanning materials, such as the sulfite cellulose process waste liquors to produce a cheaper product. This would aid in disposing of a present source of troublesome stream pollution, and would provide an abundant supply. Some progress has been made in this direction, and as we learn about the synthetic tanning materials and the lignosulfonates, we will be able to develop more effective blends. Lignosulfonates, which are components of the sulfite cellulose process waste liquors, were a component part of several successful German synthetic tanning materials.

The most noteworthy synthetic tannins that have been put on the market are known by the tradenames " Calgon ", " Exan " and " Leukanols ". The leukanols and exan are condensation products of formaldehyde with phenol sulphonic acids of varying composition, made under different conditions of condensation. Calgon is sodium hexametaphosphate. All of these materials are valuable adjuncts to the tanning process, but none of them is a replacement for vegetable tannins; they undoubtedly have tanning activity, but the leather produced by them is not entirely satisfactory. Their function rather is to increase the rate of penetration of vegetable tan-

nins and to improve the quality of the leather produced by the vegetable tannins used. Therefore, they must be considered as valuable tanning adjuncts but not as synthetic replacements for vegetable tannins. Their use decreases the amount of vegetable tannin required for leather tannage; this is one of the reasons why 75 percent of chestnut tannin was taken as the amount that could be replaced by wattle tannin. Synthetic tannin, in the true sense of the term, that is, material chemically identical with or similar to natural vegetable tannins, has been produced only as a laboratory curiosity, and the probability is that such materials will not, at least for a very long time to come, be produced commercially, because of the cost and complexity of the method of synthesis that must be employed.

The syntans, condensation products of formaldehyde with phenolsulfonic acids, although not satisfactory tanning agents in themselves, when used either prior to or in conjunction with vegetable tannins, increase the yield of leather and the extent to which the hide is plumped during tannage. Calgon acts similarly to the syntans. Perhaps wattle tannin in conjunction with either the syntans or calgon will prove to be as desirable as chestnut tannin for sole leather.

Another solution of the problem may be found in chrome retanning. Basic chromium salts give complete tannage of hides, but sole leather tanned in this way shows poor yield, and there is very little plumping; it becomes slippery when wet. Notwithstanding, chrome-tanned leather has high resistance to wear and abrasion. If chrome-tanned leather is retanned with vegetable tannin, and perhaps wattle tannin will prove ideal for this purpose, a leather with many of the desirable properties of both types of tannage is obtained. Although chrome retanning involves more operations than straight vegetable tanning, tannage is accomplished in a much shorter time; so the total cost to the tanner should not be greatly increased.

From the above it is apparent that wattle bark in conjunction with the syntans, calgon, basic chromium salts, or tannin from the California tanbark oak, will provide a complete and satisfactory replacement for the chestnut wood extract now so extensively employed. Our laboratory will investigate these possibilities, and will report its findings at a later date. It is safe, however, to assume that wattle tannin will play a more and more important part in the leather industry as chestnut disappears.

Vanillin

The odoriferous flavoring principle of the vanilla bean is mainly vanillin, chemically known as 3-methoxy-4-hydroxybenzaldehyde, or methyl protocatechuic aldehyde. It occurs in nature in the fully grown but unripe and cured fruit of *Vanilla planifolia* and *V. tahitensis,* members of the orchid family, to the extent of 1.5 percent to 3 percent. The former is native to the damp forests of eastern Mexico, but is commercially cultivated in the Isle of Reunion, the Seychelles, Java, Hawaii, Tahiti, Guadalupe and Madagascar, the last of which, along with Mexico, has for some years been our chief source of supply. The problems of collection, curing and transportation of the fruit, as well as those concerned with extraction of vanilla from it, have made the natural product commercially expensive. Because of its extensive use in food flavors, candy, pharmaceuticals and cosmetics, the synthesis of the aromatic has been investigated and developed. As a result of these investigations, it is now commercially possible to synthesize methyl protocatechuic aldehyde from guaiacol [a colorless oil obtained by synthesis from

coal tar], eugenol [contained in clove oil], coniferin [in the sap of coniferous trees] and lignaceous materials.

In recent years much attention has been given to the problem of vanillin production from lignin by the paper industry, especially by those mills employing the sulfite pulping process. One of the chief by-products of this industry is waste sulfite liquor containing mostly lignosulfonic acids. The disposal of this waste sulfite liquor has presented a problem to the industry, and if it could be utilized in a commercially feasible process, a great contribution would have been made. Other industries, such as sawmills, would derive great benefit as well, by discovery of a process which would turn their useless by-products into a commercially important product such as vanillin.

The methods of isolating lignin fall into two groups: (*a*) those which depend upon removal of the cellulose and other ingredients in the material, leaving the lignin as an insoluble residue; these methods involve the use of sulfuric, hydrochloric, hydrofluoric or phosphoric acid; (*b*) those depending upon removal of the lignin from its associates; these methods involve use of alkalis, alcohols and other reagents.

The sulfite process, with its use of sulfurous acid and calcium bisulfite, is the principal means of separating lignin from cellulose in the paper pulp industry. During the process lignin is converted into its water-soluble lignosulfonic acids, and these, when heated with alkalis, yield vanillin, a conversion that is greatly increased by elevated temperatures and pressures, and by the use of a mild organic oxidizing agent, such as nitrobenzene.

Such production of vanillin from waste sulfite liquor has been carried on commercially. Application of the process to the lignaceous material of *Yucca brevifolia* in California has been investigated, but by way of conclusion little can be said beyond regarding such production of vanillin as a problem of considerable economic interest.

Cascara

The therapeutic use of cascara as a tonic-laxative has not diminished since the drug first came onto the market some 70 years ago. Its use has rather constantly increased, and it ranks first among the American plant drugs. It is used wherever civilized medicine is practiced, practically in every country on the globe. This widespread use is especially remarkable in view of the fact that so many plant drugs have been superseded by chemicals, antibiotics, vitamins, hormones, *etc.*

The source of this bark has long been wild trees of *Rhamnus Purshiana* in the Pacific Northwest. Many persons would spend weeks or months tracking down the trees in dense mountainous forests, cutting them down and then peeling them by hand and carrying out the bark on manback or horseback.

During the last three decades cultivation of these trees has been carried on to some extent in Oregon, Washington and British Columbia, and the day will come when cultivated or semi-cultivated cascara plantations will become the source of supply, and machines will do much of the work of preparing the drug for market. It is possible that much of the cascara extract of the near future may come from the young twigs sheared annually or semi-annually from the trees of cascara groves; or from the thin bark, machine-brushed from two-year-old coppice shoots of cascara. In either case the material could be artificially dried in a few hours; artificially aged in another few hours; extracted and the extract dried within one or two days. The extract then would be assayed, adjusted to a standard and packaged for the market. Of course, dosage forms containing vari-

ous mixtures of the anthraquinone principles might eventually replace the drug itself. It seems highly probable, however, that cascara extract will retain its leading position in medicine for many years to come.

Camphor and Safrole

Former Senator George M. Biggar, then Chairman of the Senate-Assembly Interim Committee on Forestry Studies, asked for a report from our Division as to what could be done to develop camphor trees in California as a source of camphor gum, camphor oil and safrole so that in the future we would not be dependent upon the Japanese monopoly for camphor products from their source in Formosa, as we were before the war. Our Division has complied with his request. The Dodge and Olcott Company, Bayonne, New Jersey, to whom we sent an entire camphor tree from Santa Barbara for distillation and analysis, has reported that the yield and quality of the camphor gum produced compared favorably with the best in Formosa. The drug and perfume trades have asked us many times to encourage the production of camphor and safrole in California.

However, the advisability of encouraging the cultivation of camphor trees in California is not a simple question, owing to the facts that camphor of excellent quality can be produced cheaply by synthetic methods from pinene and from coal tar, and that the camphor tree (*Cinnamomum camphora*) is not the only natural source of camphor and safrole—the two components of camphor oil that are most valuable. Synthetic camphor is now official in both the U.S.P. and B.P. It is a complete and entirely satisfactory replacement for natural camphor, although synthetic camphor is racemic, while the natural from camphor trees is dextrorotatory. d-Camphor can also be obtained in satisfactory yield from camphor basil (*Ocimum kilimandscharicum*). Safrole can be produced in quantity from about ten different plants, but the following three are the most important: *Sassafras officinale, Ocotea pretiosa* and *Doryphora sassafras*. Safrole can be produced synthetically from coal tar and from anethole, but existing processes give poor yields and are expensive to operate. The advantages and disadvantages of growing camphor trees in plantation form in California can best be elucidated by comparing in detail the economic aspects of the various plants and synthetic processes.

Before the war synthetic camphor, mostly imported from Germany, sold for a few cents less per pound than natural camphor gum of Japanese origin. At present large quantities of synthetic camphor are being produced in this country from turpentine at a price that is not greatly higher than that of prewar natural camphor. Processes of manufacture are being improved continuously, and there is every reason to believe that American synthetic camphor will be able to compete in the world market with camphor from any source whatever. Were camphor the only product from the camphor tree, there is no question that camphor culture in California would be uneconomical. This, however, is not the case.

The camphor tree on distillation yields two important substances, namely, camphor and safrole, as well as a considerable quantity of terpenes which are mainly used for paint thinner. Safrole is used in soap and industrial perfumes, and it is the sole raw material from which heliotropin or piperonal is manufactured. Heliotropin is used extensively in all kinds of perfumery, and in flavors of the vanilla type. Heliotropin is irreplaceable.

The term "camphor oil" is used commonly to describe the total distillate from the camphor tree as well as various fractions thereof. Sometimes various

adjectives are employed to distinguish between these, but there is no uniformity in this regard. To facilitate clear discussion and writing, the following terminology is suggested.

All of the volatile material that can be distilled from the leaves, twigs, trunk or root of the camphor tree will be called "whole camphor oil". Whole camphor oil is a liquid at elevated temperatures, but on cooling a great deal of the camphor gum crystallizes out. The oil that remains will be termed "residual camphor oil". In commercial practice, whole camphor oil is seldom if ever produced, since the vapors that distill over are conducted into camphor houses where the camphor gum, holding mechanically considerable residual camphor oil, collects as flowers of camphor on the roof, walls and baffles, the remainder of the residual oil falling to the bottom where it runs out along with the condensed steam. The oil held mechanically by the flowers of camphor is then pressed out and combined with the rest of the residual camphor oil. Thus the unfractionated camphor oil of commerce is what we have termed "residual camphor oil".

Residual camphor oil is usually separated by fractional distillation into light and heavy camphor oils. The terms "light" and "heavy" refer to boiling point and specific gravity. On further fractionation heavy camphor oil yields a further quantity of light oil and a fraction containing 60 to 70 percent of safrole. This last fraction is known in commerce as "oil of camphor sassafrassy" or "artificial sassafras oil". Since safrole melts at 11 degrees C., sassafrassy camphor oil can also be produced by freezing oil of camphor heavy, then pressing the light camphor oil out from the frozen mass with an hydraulic press.

The whole camphor oil distilled from various parts of the camphor tree varies greatly in composition. Oil from the leaves and twigs contains the most camphor (40 percent or more), but no safrole; that from the roots has the highest safrole content and the least camphor; and that from the trunk wood contains an intermediate amount of both substances.

If an entire camphor tree were distilled and the distillates combined, the whole camphor oil so produced would have a composition somewhat as follows: camphor, 25 percent; safrole, 7.5 percent; light camphor oil, 67.5 percent. About 28 compounds have been identified in light camphor oil, but none of these has any particular commercial importance. Light camphor oil is consumed without fractionation as a paint thinner.

A 15-year-old camphor tree weighs about 3,000 pounds. The trees would be spaced 20 × 20 feet in a camphor plantation, or 105 trees per acre. The yield of whole camphor oil is on the average approximately two percent. It is not economical to harvest camphor trees much before they are 15 years old. Hence the yield of whole camphor oil from one acre of plantation would be 6,300 pounds at the end of 15 years, or 420 pounds per acre per year. This would mean a production of 105 pounds camphor, 32 pounds safrole and 283 pounds light camphor oil per acre per year. Assuming that camphor will bring 70 cents per pound, safrole 85 cents per

FIG. 5 (*Upper*). A planting of rock rose (*Cistus ladaniferus* var. *maculata*) at Arroyo Grande, San Luis Obispo County, Cal., developed to serve as a domestic source of supply of its oil and resin.

FIG. 6 (*Lower*). Young trees on a 3,000-acre planting of *Eucalyptus globulus* at Arroyo Grande, established to provide a domestic source of eucalyptus oil. At present this oil is imported from Australia and used medicinally. Tall trees in the background are *E. MacArthurii,* a source of oil containing geraniol, important to the perfume industry.

pound and light camphor oil 20 cents per pound, an acre of a camphor plantation would gross $157.30 per year.

Although no pulping tests have been run, it is probable that the wood from this tree would be of at least some value for this purpose, particularly since it has been demonstrated that strong papers and wall board can be made from short-fibered woods by incorporating small amounts of synthetic resins. Since there are many uncertainties and variables in connection with the value of this wood, no attempt has been made to set a value on it.

The cost of establishing and caring for a camphor tree plantation would not be great. On the other hand, the cost of harvesting the crop would be relatively high, owing to the fact that the roots of the trees would have to be dug because it is the roots which contain the most safrole. The greatest disadvantage of camphor tree culture is that the grower would have to wait 15 years before he obtained a return from his investment.

Although camphor is an important medicinal and large quantities of it are used for this purpose, the greatest use of camphor is in the manufacture of celluloid. This last named use is on the decline, owing to the extensive developments that have taken place in the synthetic plastics field.

Camphor basil (*Ocimum kilimandscharicum*) will yield a crop of camphor the first year, and larger amounts in succeeding years. This plant is a member of the mint family and is a perennial. It is a low-growing herb that lends itself to mechanical cutting and handling. It must be cut two or three times per year. As much as 40,000 pounds of plant material have been obtained in a year from one acre of camphor basil. This plant is a recent introduction from East Africa, and there is no doubt that experience in its culture, and selection and breeding will increase this yield. The fresh herb contains about 0.6 percent of volatile oil. Oil of camphor basil contains 60 percent or more of camphor; the balance of the oil has not been thoroughly investigated as yet, but no safrole is present. From the above data it can be deduced that one acre of a camphor basil planting will yield 144 pounds of camphor per year. In Virginia under exceptional conditions as much as 300 pounds of camphor have been obtained from one acre in a year. In California, where a long growing season is possible, an even greater yield might be obtained.

Sassafras radix (*Sassafras officinale*) is the plant from which sassafras oil is distilled in the eastern part of the United States. This oil contains about 80 percent of safrole. Sassafras oil has a fine flavor, and considerable quantities of it are used for this purpose as well as in medicine as a carminative. Only the root contains sufficient oil to make commercial distillation feasible. The result is that sassafras oil is relatively expensive, and will always be so. Hence, sassafras oil is eliminated as a source of commercial safrole for the manufacture of heliotropin.

During the war our imports of residual camphor oil were cut off. Another source of safrole had to be found. The Brazilian sassafras tree (*Ocotea pretiosa* or *O. cymbarum*) furnished a solution to this problem. The wood of this tree contains about 0.5 percent of an oil bearing about 85 percent of safrole. No safrole is present in the leaves. *Ocotea pretiosa* is a slow growing tree, and grows wild in the forests of Brazil. No attempt has been made to grow this tree in plantation form. Ocotea oil sells in the American market at the present time for 85 cents per pound. It is estimated that there is sufficient ocotea near transportation in Brazil to supply the world with safrole for ten to 15 years. The remainder of the ocotea is remote, and the cost of producing the oil would be much

greater than at present. It is doubtful that this tree would prosper in California.

An Australian shrub, *Doryphora sassafras*, is the only plant on record that contains safrole in its leaves. The leaves and twigs yield one percent of an essential oil which contains about 60 percent of safrole. *Doryphora sassafras* is a shrub growing to a height of about ten feet. Our Division does not have data on its rate of growth. It has never been used as a commercial source of safrole. It is most probable that *Doryphora* will prosper well in California. It is propagated by seed. Since the safrole is in the leaves, this plant could be grown in plantation form and harvested mechanically. It holds considerable promise as a commercial source of safrole, and is included in our schedule of demonstration plantings.

Castor Beans

Owing to the fact that there is a world-wide shortage of castor oil, interest in the production of castor beans in the United States has recently increased very greatly. The reasons for this shortage of castor oil are two; first, the recent war has taught us that castor oil can be changed chemically so as to produce an excellent drying oil for the manufacture of paint; and second, castor beans are not being produced in foreign countries in the same volume as before the war because these foreign countries are primarily interested now in the production of food crops. The result is that castor beans are scarce and high in price.

The production of castor oil has evolved into an industrial business of major proportions. Research in chemistry and industry has multiplied greatly the uses to which the oil can be put. Contrary to the concept many of us acquired in childhood, only a very small percentage of it goes into pharmaceutical uses. Over 99 percent is used industrially in one form or another. The paint and varnish industry, one of the largest buyers of castor oil, uses it for a superior quality drying oil in many high-grade paints and varnishes, including insulating varnishes for cable and electrical equipment, alkali- and water-resistant paint, and enamel. The plastics industry buys castor oil to be used in the manufacture of a variety of coated cloths and simulated leathers, also for the production of alkyd resins. Castor oil is also used in the processing of fabrics, in breaking emulsions that occur in crude petroleum and as a constituent of hydraulic fluids. The Baker Castor Oil Company, alone, produces over one hundred products from castor beans.

Castor beans are borne on spikes of capsules, each capsule containing usually three, but sometimes four, beans. All of the beans on a spike never mature at the same time. In many varieties the capsules drop off the spike when the beans are mature, *i.e.*, shattering occurs. Also, many varieties dehisce; *i.e.*, the capsules split open and eject the beans when these are ripe. Varieties of beans that shatter or dehisce must be harvested capsule by capsule, by hand, as is now being done in foreign countries. In order to make machine harvesting, or harvesting of entire spikes by hand, possible, varieties of castor beans must be found which neither dehisce nor shatter. If this requirement is not fulfilled, the growth of castor beans in America, with our high labor cost, will not be profitable.

The extent and nature of the market for castor oil and its derivatives make quite evident the desirability of producing the raw material in this country. It is estimated that a third of a million acres of castor beans would be required to meet the present market for products made from the seed.

Castor plants are common as wild and dooryard plants throughout the State of California. Castor beans have been planted freely for shade and ornamental

purposes and are to be seen wherever any sizable settlement of people occurs. Presumably, these plants are traceable to the reported introduction of castor beans—when the old Spanish missions were being established in the late 1700's. Natural distribution has been aided by enterprising seed companies who have collected small quantities of seed from these plants and have sold them over the counter, neatly and attractively packaged, as mixed varieties of castor beans.

The wide distribution of this plant is significant in revealing the general suitability of the California climate for castor bean growth, and the ability of the castor bean to survive under a wide range of growing conditions. It is important to note, however, that most of these plants are not of suitable agricultural type. No wild plant has been found to have all of the desirable plant and seed characters in the highest degree, but a few have been found which merit their use as commercial varieties, pending development of superior types by technical plant breeding.

We have no reports of extensive attempts at commercial production of castor beans in California. However, a few acres were planted in 1918, principally in the Imperial Valley. These attempts were essentially unsuccessful and were discontinued at the end of the first year for lack of direction and incentive.

Coincident with the attempted commercial acreages during the first World War, a number of tests to compare varieties were conducted by some of the research stations in the State. Results of these tests have not become generally known.

During the Second World War the Federal Government once more became concerned about the supply of this strategic material, and again promoted some research work and commercial acreages of the crop. Some variety tests were made in this as well as other States, and variety-improvement work was begun by individual members of the California Agricultural Experiment Station staff, including the late Dr. Guilbert, the late Professor Mackey and Mr. Goar. Once again work was terminated at the end of the war for lack of adequate incentive.

The variety developed by the United States Department of Agriculture at Beltsville, Maryland, which does not dehisce, and which we felt to be best adapted to California conditions, is known as the Conner variety. Since the productivity of the Conner variety did not appear to be so great as that of several varieties of beans found growing wild in the State, observations of these wild plants were made to determine whether or not they dehisce or shatter. It was found that several of them behave excellently in this regard, and seed of such varieties was gathered for trial plantings. For purposes of clarity these wild castor bean varieties have been named by us after the localities in which they were found, or after the individual who found them. Several trial plantings have been made on various soil types in California, on both irrigated and dry land, to determine whether they would be a profitable field crop here. Our observations during the past season would indicate that castor beans grown on irrigated land should be treated as an annual It does not seem that it would be practical to grow them as a perennial crop, since the plants would have to be cut down each year, and disposal of the residue would be too costly. When castor beans are grown for the production of seed for increased plantings, it is essential to keep the strain pure. This can best be done by removing wild and ornamental plants adjacent to the fields in order to prevent cross pollination.

To avoid the pitfalls that doomed to failure the earlier attempts at commercial production in this State, certain precautions have been taken. The problem

of providing a direct market for the beans is automatically taken care of by the well-located Los Angeles mill of The Baker Castor Oil Company. The Baker Castor Oil Company is providing additional market insurance to the farmers by contracting, prior to planting time, to buy all of the castor beans produced. This contract provides a floor price for the beans, thereby eliminating the danger to the grower of extreme and unexpected reduction in market price during the growing season. The contract further eliminates certain of the problems that confront prospective growers of castor beans by providing for availability of proven seed and making hulling equipment available.

Additional precautions are being taken by accumulating, prior to any production effort, a fund of information so that the Baker Castor Oil Company can wisely select areas for production and safely recommend particular varieties and cultural methods to contract holders. A comprehensive well-integrated research program has been initiated by the Company in cooperation with State and Federal agencies, the State Extension Service, and active farmers and producers throughout the State. Dr. Kidder and his assistant, Mr. Scott, of the California Polytechnic School, have devoted a great deal of effort to several phases of the program. Dr. Madsen, Dr. Briggs and Mr. Goar of the State Experimental Station have taken an active part in the variety testing. Mr. Gardner and others of the Extension Service staff are cooperating, as are many prominent farmers and agricultural leaders. It is in the active support of these groups that the strength of the program lies, and much tribute is due those cooperators.

The research program is designed to determine climatic and economic adaptability of the castor bean to each of the major agricultural areas in the State, to find out which of the present varieties is most suitable in each area and, through technical plant breeding, to develop new, improved varieties for those particular areas of good adaptation where none of the present varieties meets the exacting tests of production. The research program is also investigating the general soil requirements of the crop and the most efficient cultural practices for each area, and is developing machinery and techniques for production from planting through harvesting and hulling of the crop. Economic data are being collected as a basis for comparison of castor beans with other crops. The seed stocks of the newly developed varieties are being increased from the few seeds now on hand to quantities sufficient to plant a sizeable acreage. Many other pertinent items are being studied, such as the oil content and hulling percentage at each location, development of grading standards, weight per bushel and number of seeds per pound. In addition to the work that is being done here in California, a great deal is being learned in nearby Arizona which will have direct application to parts of California. As can be seen, the entire program is taking on enormous proportions. Continued cooperation from all parties concerned is essential for its ultimate success.

It has been well established that castor beans can be produced economically in California. Yields ranging from 1,500 to 3,000 pounds per acre have been obtained on good, irrigated land where proper production practices have been followed. The average price of castor beans for the past year was ten cents per pound, the attractiveness of the crop matched that of most of our major crops, and the production costs were low as compared to most crops. The crop responded well to good soils and good treatment, but at the same time has a high tolerance for less favorable conditions. No evidence of disease or insect damage has arisen as a serious produc-

tion hazard in any of the major areas under observation. The small seed stocks of certain of the best varieties have been increased, and a small nucleus acreage is planned for next year where these varieties perform the best.

Castor beans are a crop that can be produced at low cost. Very little cultivation is required. Due to the rapid growth of castor beans and shading of the ground, weed control costs are far below those for other crops. Our observations lead us to believe that castor beans have no insect pests, since we have had no damage from insects whatsoever. However, when the plants are young and tender, that is, just after they have come up, there is some difficulty with cut worms. This can be controlled by dusting with five percent DDT dust or with chlordane.

As a crop for marginal land it would seem that castor beans are ideal. On the Arroyo Grande Mesa, where practically all crops have to be protected from deer and rabbits, no damage from these sources has occurred. Gophers destroy an occasional plant, but apparently they do not forage on castor beans. The slight damage was caused from burrowing. Present indications are that castor beans can be grown on dry land as a perennial crop. Yields in the second and subsequent years should be considerably greater than those recorded for the first year. Cultivation and weed control should be considerably less in the second year and thereafter, as the beans will make a vigorous early growth and outcompete slower growing weeds. Addition of nitrogen fertilizer in proportion to the amount of moisture the season affords will undoubtedly increase the yield.

From the above it would seem that the growth of castor beans on dry marginal land would be profitable to the grower, particularly after the first year. The writer feels that a production of 2,000 pounds per acre is to be expected—worth, at present market price, $240. This is a handsome return from land worth only from $15 to $20 per acre.

It is hoped and believed that, as a result of this basic coordinated work, castor beans will soon be produced and processed in California for the mutual benefit of California's agriculture and California's industry.

Thymol

Thymol is a crystalline substance obtained by caustic extraction from various volatile oils. It was first discovered in oil of thyme (*Thymus vulgaris*), and is used principally in medicine and as a fungicide, being an effective anthelmintic against hookworms. Because of its antiseptic properties it is employed as an ingredient of many oral and nasal preparations, such as toothpastes and mouth washes, and is used commercially also as a fungicide in plastics. Until 1920 it was obtained wholly from volatile oils, but at present practically all thymol production is synthetic. It is produced in the United States today by three firms, two of them manufacturing it from oil of *Eucalyptus dives*, the third from coal tar. Imports have come from Germany, Australia and the United Kingdom.

Thymol may be manufactured also from umbellulone which is a component to the extent of 40 to 60 percent in the essential oil obtained from the leaves and twigs of the California bay or laurel tree (*Umbellularia Californica*). This evergreen tree grows throughout almost the entire State of California and in southern Oregon, attaining a height of 60 to 80 feet in the latter area. This height makes it impractical to harvest the leaves, but in California the tree appears in a many-stemmed shrubby form in clumps and thickets from ten to

15 feet tall. In this condition harvesting is a comparatively simple matter. New leaves are produced throughout the summer, and the twigs which bear them grow constantly in length and are heavily foliaged. Usually the leaves of a season's growth persist on the branches about two years, but frequently some are retained five or six years.

Possible industrial use of this source has been investigated, but it is concluded that production of thymol from California bay tree oil is not a feasible commercial undertaking, unless the other components of the oil are recovered and utilized.

Sweet Basil

Four varieties of sweet basil have been distilled in Europe as sources of sweet basil oil: *Ocimum basilicum* var. *crispum*, var. *thyrsiflorum*, var. *album* and var. *purpurascens*. The oils from these four varieties are quite similar in physical and chemical characteristics, but the yield from *crispum* is the greatest.

FIG. 7. A distillation plant at McFarland, Cal., consisting of four 10,000-gallon stills, for the recovery of menthol from Japanese mint (*Mentha arvensis* var. *piperascens*). The adjoining planting of the mint to feed the stills is the only such commercial planting at present in the United States, and brings in a gross annual revenue of $20,000 to $22,000.

In 1946 and 1947 sweet basil oil was distilled commercially in California from plants, supposedly of the variety *crispum*, grown in the State by Mr. A. R. Martin of McFarland. The amounts produced were 50 and 170 pounds, respectively. Since there were chemical differences be-

tween this oil and that of Europe, there is a question as to whether true *crispum* was used. In summary, however, it can be said that sweet basil oil can be produced satisfactorily in California. Although California oils differ from those produced in Europe, they have excellent odor value which can be utilized by the perfume and flavoring industries. Further, the addition of methyl chavicol or anethole to California oils changes their odor value so that they become almost identical with oils distilled in Europe. The production of sweet basil oil will be profitable to the California grower if the weed control problem can be solved.

The Need for an Essential Oil Industry in the United States

The present world economic situation is such that the supply of raw materials for the pharmaceutical, flavoring and perfume industries is tremendously upset. Never before in the history of these industries has the condition been so chaotic. During the war the industry felt acutely the necessity of American independence in the growth, cultivation and production of many of the botanicals necessary for the manufacture of the essential oils used in the pharmaceutical, medicinal, flavoring, perfume and other industries. The coming of peace has eased this situation somewhat, but shortage in supplies of these materials is still world-wide. Further, sources of supply in foreign countries are still very unstable and, for this reason, unsatisfactory. There is no reason to believe from present indications that this situation will correct itself in the foreseeable future. The only way in which a stable and satisfactory source of these raw materials can be attained is for them to be produced in this country.

In our industry we felt this necessity during the first world war and even more so during the second. After the first world war we became completely independent in the production of aromatic chemicals, such as alcohols, esters, aldehydes, ketones, lactones, as well as many other products. This, however, did not apply to essential oils.

It is true that from small laboratories in the United States prior to the first world war our industry has grown to gigantic plants. These developments were the result of the miraculous growth of demand for flavoring and perfume materials. The tremendously increasing demand for better tasting foods and better smelling toilet preparations has created the necessity for developing the industry to what it has become in recent years.

These developments were made possible by organic and compounding chemists. The former have developed the production of essential aromatics, and the latter knew how to blend these into flavoring and perfume compounds to produce the best results for the purposes intended.

During the past 60 years there have been numerous discoveries and tremendous developments achieved in Europe, as well as in the United States, in the field of production of flavoring and perfume materials. The raw materials used in these fields cannot be very well separated. Since the last quarter of the last century, following the perseverance and research of such scientists as Wallach, Dumas, Tiemann and others, a great deal of scientific literature has been published, throwing much enlightenment on research and developments made in the production of essential oils, their derivatives and aromatics. Among authors were well-known scientists, such as Georg Cohn, Gildmeister, Hoffman, Klimont and many others.

Wallach actually succeeded in deciphering "The Riddle of Essential Oil Components" in the preparation of isolates, such as citral from lemongrass (*Cymbopogon citratus*), geraniol and

citronellol from citronella (*Cymbopogon nardus*), anethol from anise oil (*Pimpinella Anisum*), carvone from caraway oil (*Carum Carvi*), cinnamic aldehyde from cassia (*Cinnamomum Cassia*) and many other isolates; also in separating hydrocarbons from essential oils—the fundamental work from which deterpenized essential oils have been developed. These are used to a great extent at present in the perfume and flavoring industries. By experience we learned how to utilize and purify these by-product hydrocarbons which are becoming more and more useful. These are applied in various industries where an inexpensive pleasant odor is desired, or where there is the necessity to cover some unpleasant odor present in the original product.

There were Tieman's discoveries of vanillin and ionone in the last quarter of the nineteenth century. Progress in the discovery of synthetic aromatics and essential oil derivatives began and contined at such a pace that just at the turn of the century it became a large industry, particularly in Germany. Studies in the field of flavoring materials started parallel to the investigation of the natural products used in the perfume industry. It was definitely found that the odoriferous principles of jasmine were benzyl acetate, indole, methyl anthranilate, linalool, jasmone, *etc.* The components of neroli were identified as methyl anthranilate, linalool, citral, indole, *etc.* The components of rose were found to be geraniol, phenylethyl alcohol, citronellol, *etc.*

It was found that vanillin is the aromatic flavoring principle of the vanilla bean (*Vanilla* sp.), while the tonka bean's (*Dipteryx* sp.) flavoring value is due to the presence of coumarin together with a small percentage of other aromatics. Isoamyl acetate was found in banana (*Musa* sp.) and methyl salicylate in wintergreen (*Gaultheria* sp.), while clove oil (*Eugenia caryophyllata*) definitely yielded eugenol; anethol was derived from anise (*Pimpinella Anisum*), irone from orris (*Iris* sp.) and jasmone from jasmine (*Jasminum* sp.). It was Albert Hesse, in Leipzig, who conducted extensive research to identify components of various natural essential oils.

Before World War I the production of aromatic chemicals in the United States, with the exception of vanillin, coumarin and methyl salicylate, was practically nil. Very few of the products were made; and such products as geraniol, linalool, citral, benzaldehyde and cinnamic aldehyde were made on a laboratory scale only.

The necessity for the production of aromatics in the United States was recognized during the first world conflict. Due to the might of American perseverance, this industry grew to an enormous size during the peace period between World War I and II. Many developments took place, which, during the depression years, were somewhat neglected; but, on the whole, the desire of the industry to become independent from foreign influence and supplies was successfully achieved.

We must realize that for the production of aromatics we have to depend on two sources of supply for raw materials; first, on natural essential oils, which source is very important; and second, on such products as toluene, phenol, cresols and naphthol. There is no need to go into a description of the methods used in production of perfume and flavoring substances from the second category, since they have already been successfully developed in the United States. What we are most concerned with is the cultivation and growth of materials used in the production of essential oils.

Some essential oils have been distilled in the United States since the beginning of the nineteenth century. Wintergreen (*Gaultheria* sp.), sweet birch, (*Betula lenta*), wormwood (*Artemisia Absin-*

thium) and sassafras (*Sassafras albidum*) were distilled in crude stills. Since then the manufacture of these products has grown extensively. Some of these essential oils were exported to Europe before the second world war.

The United States is in a position to supply not only its own needs but also the needs of other countries with such essential oils as orange and lemon, for which products, not so long ago, we depended exclusively upon importation from Italy or Spain. The production of citrus oils has grown enormously. These oils—lemon, orange, grapefruit, tangerine and others—are produced in California, Florida, Arizona and Texas, and in quality are as good as the best imported oils.

Oil of peppermint (*Mentha piperita*) has been produced in upper New York State, Indiana and Michigan. In recent years, in the northern Pacific States of Oregon and Washington, the production of peppermint and dill weed (*Anethum graveolens*) oil has been developed. The latter is also produced in Montana. Other essential oils have also been produced in the United States, but our concern at present is the production of oils heretofore not produced in this country. Such a step is being taken by the Drug and Oil Plant Project of the California State Polytechnic College, and through their efforts many successful attempts have already been made to produce essential oils heretofore imported from other continents.

One of these oils, now produced commercially by California growers, is oil of sweet basil (*Ocimum basilicum*). The spearmint oil (*Mentha spicata*) produced in California is of excellent quality, meeting all the required specifications as to carvone, *etc.* Samples of celery oil (*Apium graveolens*), very important in the flavoring industry, and many other essential oils distilled in California from California grown botanicals have also been found to be of excellent quality.

Among other botanicals worthy of cultivation in California is coriander (*Coriandrum sativum*). The fruit, upon distillation, yields an essential oil which is a U.S.P. product. This oil is very rich in linalool, also decyl aldehyde. Linalyl acetate, geraniol, citronellol and their esters, as well as citral, can be made from linalool. Ionone and methyl ionone can be produced from citral. As a matter of fact, many other products can be manufactured using oil of coriander as a starting point. It may well be taken into consideration that these essential aromatics produced from coriander oil are finer in odor than products manufactured from the usual commercial essential oils, such as lemongrass (*Cymbopogon citratus*), linaloe (wood of Mexican *Bursera Delepechianum* and *D. Aloeoxylon*), bois de rose (wood of *Aniba panurensis* of Guiana) and citronella (leaves of *Citronella Nardus* and *C. Winterianus*).

Another product of importance in our industry is oil of anise (*Pimpinella anisum*). The origin of anise is not exactly known. There are some indications that it came from Asia Minor and others that it came from Egypt. It is now found in large quantities in Asia and in practically all parts of the world. Most of the markets are supplied by China; however, large amounts were produced in Russia, Holland, Germany, Moravia, Bohemia, Scandinavia, France, Spain, Bulgaria and Turkey. One acre of cultivated anise furnishes approximately 2,000 pounds of anise seed which yields the oil. If climatic conditions are proper, the yield might be greatly increased. Anise oil is accepted by the U.S.P. for use in preparing aqua anisi and spiritus anisi, anise syrup and tincture of anise. It is also used in preparations for preventing and curing dysentery. Liqueurs can be prepared from it, and it is used in many combinations in baking and in the candy industry. It possesses a strong licorice flavor, and is used for that purpose in

candies, cough drops, medicinal and dental preparations. Anise oil contains from 80 to 95 percent anethol. From anethol, anisic aldehyde (aubepine) can be produced, and the latter is used extensively in various perfume compounds, such as lilac, lily and hyacinth. The most important component of anise seed is its essential oil. The largest yield is obtained from Italian and Spanish seeds, the normal being from 2 to 3.5 percent.

The hyssop plant, *Hyssopus officinalis*, grows 12 to 20 inches in height, and its leaves, formed on opposite sides of the stem, look like spears. Hyssop is cultivated on the dry slopes of southern Europe and central Asia, and for production of its oil the whole plant above ground is utilized, mostly in the production of liqueurs, being indispensable in the compounding of benedictine, chartreuse and other liqueurs. In French cuisine an essence or extract is prepared from the plant or its essential oil. Having a spicy taste and aroma, it can also be used in perfumery in modern creations where a spice odor is desired. The oil, distilled by means of live steam, is of a yellowish-green color and has a distinct taste of the plant itself.

Other botanicals suggested for cultivation in California as having flavoring, perfume, and some of them, medicinal value, are as follows:

Coluria geoides, which, by steam distillation, yields an essential oil containing 99 percent eugenol, the latter a U.S.P. product. Eugenol is used in pharmaceutical and dental preparations, in flavoring foods and in the perfume industry as a spice odor. It is important to mention that eugenol is used also as a starting point in the production of eugenol vanillin, for which there is constant demand; and also to make iso-eugenol and its derivatives which are indispensable in the perfume industry.

Lovage (*Levisticum officinale*), used in the flavoring industry as one of the components of artificial maple. It is also used in liqueurs. Other products are calamus root (*Acorus Calamus*), pot marjoram (*Origanum vulgare*), angelica seed and root, sweet marjoram (*Origanum majorana*), balm (*Melissa officinalis*), caraway (*Carum Carvi*), fennel seed (*Foeniculum vulgare*), estragon (*Artemisia Dracunculus*) and many others.

The production of essential oils has been carried on for many centuries. The Chinese production of cassia oil (*Cinnamomum Cassia*) and anise oil is as ancient as the history of China itself. Of course, as time went on, methods of distilling essential oils have improved. Besides this, other methods, such as maceration and volatile solvent extraction, have been developed for isolating odorous products from natural sources.

In producing essential oils it is important not only to obtain a product of proper quality but also to determine how such essential oils can be used to the greatest advantage. To this end compounders' services are of great help to the industry. In many cases single distilled essential oils can be utilized to greatest advantage, but very often rectified essential oils and their isolates are more useful.

It is desirable that essential oils be produced near enough geographically to the user so that the producer and the user can interchange ideas. This is another reason why essential oil production in the United States should be stimulated. The Pacific Coast, particularly California, geographically and climatically, is well suited to the cultivation of the botanicals necessary for the production of many essential oils. With the aid of agricultural controls this should present an important economic achievement to the grower and the community in general, particularly when prices and conditions normalize. If it pays to grow alfalfa, it surely will pay to grow dill weed or other botanicals for essential oils.

In conclusion, we want to point out that the development of the production of essential oils in the United States is necessary to the stability of the aromatic chemicals, flavoring and perfume industries. This is true, not only because many essential oils are used in flavoring and perfumery in large volume as such, but also because the well established aromatic chemical industry depends upon many of the essential oils as raw materials, and hence it can never be more stable than its sources of supply of such materials.

Summary

In from ten to 15 years the world's supply of tannin for leather manufacture will be seriously short; this will be especially true of the United States. American chestnut will be entirely exhausted by that time, and replanting is impossible because of the chestnut blight. Wattle culture in California as a source of tannin is feasible and will be a profitable industry. Three million acres of California Tanbark Oak can also be profitably exploited as another source of much needed pyrogallol tannins.

Yucca is a material from which vanillin can be manufactured profitably.

Safrole can best be produced in the United States from the Australian plant *Doryphora sassafras*.

A domestic source of castor beans for castor oil is most desirable because castor oil is now being utilized in large volume by several important American industries. Sufficient experimental and pioneering work has been done in California to demonstrate that castor beans are a profitable crop to the grower there.

The essential oil from the California bay tree (*Umbellularia californica*) is an important potential source of thymol. Many of the difficulties of this development have already been solved by the Drug and Oil Plant Division.

Sweet Basil oil, peppermint oil, spearmint oil and Japanese mint oil of excellent quality have been produced commercially in California. Pioneering work in California leading toward the production of several other essential oils has also been successfully carried out.

Articles Abstracted

All originally published in the Proceedings of the Third Annual Conference on the Cultivation of Drug and Associated Economic Plants in California.

Lignin and vanillin from *Yucca brevifolia* of California. Alexander Katz, President, F. Ritter & Co., Los Angeles; Alvah G. Hall, Dean, College of Pharmacy, University of Southern California; Robert Petersen.

The pharmacy of *Cascara Sagrada*. E. N. Gathercoal, Professor Emeritus of Pharmacognosy, College of Pharmacy, University of Illinois.

Field and nursery experience with essential oil crops at Arroyo Grande, California. Walter D. Scott, Field Superintendent, Drug and Oil Plant Division, California State Polytechnic College.

California tanbark oak—Its immediate availability and possibilities as a source of tannin and wood pulp. Monroe C. Kidder and Wm. H. Finney, Director and Technical Assistant to the Director, Drug and Oil Plant Division, California State Polytechnic College.

The commercial development of acacia wattle trees in California as a source of tannin and wood pulp. Monroe C. Kidder and Wm. H. Finney.

The necessity and feasibility of the commercial development of the California tanbark oak for tannin and wood pulp. E. S. Flinn, Manager, Tannin Extract Division, The Mead Corporation, Lynchburg, Va.

The availability of vegetable tannins. Fred O'Flaherty, Director, Tanners Council Research Laboratory, University of Cincinnati; Robert M. Loller, Associate Professor of Leather Research.

Possibilities of camphor and safrole production in California. Monroe C. Kidder and Wm. H. Finney.

The need for the development of an essential oil industry in the United States. Alexander Katz.

California sweet basil oil. Wm. H. Finney; Carlos E. Warriner, Analytical Organic Chemist, California State Polytechnic College.

Production of thymol from California Bay tree Oil. Robert S. Aries, Brooklyn Polytechnic Institute; Monroe C. Kidder.

MATÉ—*South American or Paraguay Tea*

This beverage, imbibed by 20 million South Americans in Brazil, Paraguay and Argentina, is prepared by brewing the leaves of a species of holly. Annual production is in excess of 200,000 metric tons of dried leaves, and physiological effects in addition to the stimulation resulting from its caffein content are attributed to the beverage.

R. HOWARD PORTER
American International Association, Brazil

Maté, or South American tea, is the common drink of nearly 20,000,000 people in South America. Its consumption has extended in small amounts to Europe, Australia and North America. The drink is made from the leaves of species of the genus *Ilex*. It is estimated that 200,000 metric tons of dry maté are produced annually, and the product constitutes an important item of export from both Brazil and Paraguay.

History

Martins states that the earliest use of maté was by the Quichuas, aborigines of Peru, whom the Spanish invaders met when they conquered the Incas. Remnants of maté and articles used in its consumption were found in pre-Columbian tombs of Ancon near Lima. This circumstance has revealed that the drink made from the maté plant became famous and common among the early inhabitants of the South American continent. The word "mati", or "maté", is a Quichua word, according to Alcides d'Orbigny, and signifies cabaca (gourd), or cuia (dried gourd used as a cup). The name "maté" came to mean the contents of the cuia, namely, the drink made by an infusion of the leaves of herva (*Ilex*) taken in the cuia (maté).

When the Spaniards occupied Paraguay they observed that the Guarani Indians used the dried and powdered leaves of caá, or herva, as a drink which the Indians believed had the property of stimulating resistance to fatigue among tribes on the march. The Spaniards began to use it and believed that its continued use gave a physical sensation and a moral value to life which alleviated fatigue and apprehension. Use of maté thus became common among the white immigrants, and in centers where caá was not native it became necessary to import it. Caá is indigenous in the territory drained by the Paraná, Paraguay and Uruguay rivers, growing wild in the forests. The Governor of Paraguay, therefore, gave the Spaniards the right to command the Indians to collect leaves for export. In reality the Indians became slaves, and any tribes that refused to submit passively to slavery were conquered by force of arms and distributed among their conquerors to serve as slaves.

Early Spanish law in Paraguay provided for some humanitarian restrictions in that slave holders were not to sell, maltreat or abandon their slaves when sick or old, but such restrictions were not commonly respected. Three small Spanish colonies were established in 1554, 1557 and 1576 for the purpose of collecting maté and transporting it to other areas. In one of these colonies there

were 100 white men and 150,000 Guarani Indians. These colonies marked the beginning of the commerce with maté, and although they were established before the advent of the Jesuits in 1578, it was the Jesuit priests who gradually extended their dominion over almost the entire area in which maté was indigenous, and thus they become the agency which literally controlled the entire maté industry. In spite of the fact that the Jesuits recognized that the traffic in maté was the principal motive for the enslavement of the Indians, they continued to develop the industry, and throughout the Jesuit domain the Indians continued to gather maté which in time became a very profitable enterprise. Maté production required long journeys, with the result that agriculture was neglected, the Indians had a very poor diet and they became addicted to excessive use of maté.

According to Muello, the Jesuits gave attention to the planting of maté, the selection of improved varieties and better methods of handling the product. Under their direction many plantings were made from seeds and transplants which concentrated the production in colonies. In this way they gained control and domination over the area in which the maté tree is native. It is believed that the Jesuits undertook the cultivation of maté because they feared that the Indians who were sent on long journeys would not return. It was considered that the cultivated maté was superior to that in the forests. The work of the Jesuits continued until 1767 when they were banished from South America by the Spanish and the Portuguese.

Martins states that the knowledge of maté was introduced into Brazil by the Bandeirantes who invaded eastern Paraguay between 1628 and 1632. They destroyed Spanish cities and hamlets and brought back with them thousands of Indian prisoners and information concerning the use of maté as a drink. From this beginning the use of maté was extended to other parts of Brazil.

Botany

The plants from which maté is obtained are included in several species of the genus *Ilex* in the family Aquifoleaceae. There are about 60 species of *Ilex* distributed in Brazil, and it is claimed that one-third of these are used to adulterate genuine maté. The adulteration is contrary to Brazilian and Paraguayan laws, yet in the early commerce with maté the natives were unable to distinguish species, and no doubt this difficulty persists to some extent at the present time.

Genuine maté was classified by St. Hilaire as *Ilex paraguariensis,* and he recognized three varieties, namely, *obtusifolia, acutifolia* and *angustifolia.* Muello states that the men (yerbateros) who collect maté call varieties of genuine maté by the following names:

$$\left.\begin{array}{l}\text{Yerba Caá amarilla}\\ \text{Yerba Caá colorado}\end{array}\right\}\text{Large leaves}$$

Yerba Caá mini — Small leaves

According to Martins, *Ilex paraguariensis* has three varieties, *genuina, parvifolia* and *latifolia,* and the former has five forms, of which the two principal ones are *forma domestica* Reiss. and *forma sorbilis* (Reiss.) Loes.

Of the 60 species of *Ilex* in Brazil, Martins states that they exist in 11 States as follows:

2 species in Pará, Ceará and Pernambuco
32 species in Minas Gerais
23 species in Rio de Janeiro
13 species in São Paulo and Goiás
12 species in Paraná, Santa Catarina, Rio Grande do Sul, and Matto Grosso

The species most commonly used to adulterate genuine maté are:

Ilex curitybensis Miers
Ilex amara (Vell.) Loes. var. *latifolia* (Bonpl.) Loes. *forma microphila*
Ilex domestica Reiss., vars. *pubescens* and *glabra*
Ilex loranthoides Mart.
Ilex cuyabensis Reiss.

FIG. 1. Maté trees (*Ilex paraguariensis*) in Brazil, over-topped by Paraná pines (*Araucaria braziliensis*).

Ilex chamaedryfolia Reiss.
Ilex brevicuspis Reiss.
Ilex dumosa Reiss.
Ilex gigantea (Bonpl.) Loes.
Ilex pseudobuxus Reiss.
Ilex theezans Mart. var. *acrodonta* (Reiss.) Loes.
Ilex integerinna (Vell.) Reiss.

Many common names have been given to genuine maté, *Ilex paraguariensis* St. Hilaire. They include herva maté, yerba maté, Congonha, Congonhinha, Caá guazú, Té del Paraguay, Té Argentino y Brasileño and Chá de Mate.

Genuine maté, var. *genuina*, is a tree which under cultivation reaches a height of four to six meters, but in the wild state when unmolested it may become ten, 20 and 30 meters tall with trunks 70 to 80 centimeters in diameter. The leaves are persistent, alternate, coriaceous, cuniform, oval or elliptical with the border somewhat dentate. They are three to 20 centimeters long and two to nine centimeters wide, dark green in color.

The anatomy and histology of the leaves of different species of *Ilex* have been studied in detail, and the differences are claimed to be sufficiently dis-

tinct to permit those familiar with the characteristics of each to determine whether maté has been adulterated.

The flowers are dioecio-polygamous, forming false panicles in the leaf axils and at the bases of the small branches. Each flower has four (some species five) petals and an equal number of stamens. The fruits are produced in racemes, and each fruit is a drupe somewhat globose to elliptical in shape and six to seven by five to six millimeters in size. When ripe the fruits are violet to almost black in color. Each fruit usually contains four seeds. The flowers appear from September to November, depending on the latitude, and the fruits mature from December to March.

Natural Habitat and Longevity

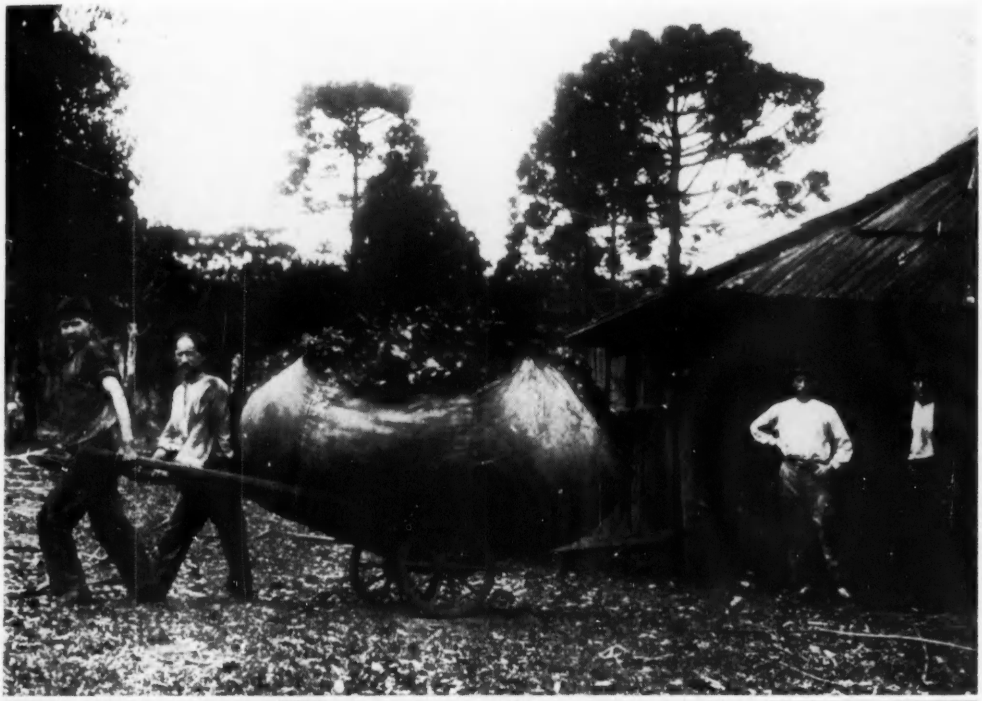
Genuine maté grows naturally between 18° and 25° of south latitude and has been cultivated as far south as 30°. Its east–west distribution is from the Atlantic Ocean to the Paraguay River. It is harvested commercially in the Brazilian States of Mato Grosso, Paraná, Santa Catarina and Rio Grande do Sul, in Paraguay and in the Misiones area of Argentina.

A tree properly handled increases in productivity up to 25 to 30 years of age. In the wild state it is calculated that trees live 100 years, and it is claimed by some that trees exist today which date from the time of the Jesuits. During the Paraguayan wars the wild trees were exploited, production declined and prices increased. Following the wars the production of maté was stimulated.

Harvesting, Curing and Processing

Harvesting consists of cutting large branches from the trees by means of a machete or other tool. Under good management a cut is made every three or four years from any one tree; otherwise the length of life of the tree is reduced. These branches with green leaves are carried to a central place where they are passed rapidly through a flame. Muello states that a flame temperature of 250° C. for 30 to 40 seconds is the most favorable for preserving the green color and reducing the moisture content of the leaves by 25 percent. Preservation of color is an important requisite. If properly done, the bitter flavor is also largely eliminated within six days. A mechanical procedure for treating the fresh leaves and branches is to pass them through a perforated iron cylinder which gyrates on an inclined plane. The cylinder is placed over the fire so that the leaves receive heat directly for a few minutes. This first process is called " sapeco ", and the cylinder with the fire is called " sapecadora ".

After this first conditioning the leaves are separated from the twigs and branches and taken to the barbaqua for further treatment or toasting. The barbaqua may consist of a crude framework of posts with a grass roof and a layer of curved lath or bamboo half-way between the roof and the ground. The leaves are placed on the frame of lath, a fire is built outside the structure and the leaves receive heat indirectly. A more modern barbaqua consists of a well constructed room with a ventilator in the roof and a frame above the floor to hold the maté leaves. The fire is built in a small structure a short distance from the "maté room ", and the heat is conducted to the maté by means of a tunnel or tube. The length of time of exposure to heat varies from ten to 24 hours, depending on the type and structure of the barbaqua. The preferred temperature to which the leaves are submitted is 80° to 110° C. Muello refers to the chemist F. P. Lavalle who analyzed leaves of yerba maté toasted at temperatures of 80, 100 and 130° C. and found that the respective percentages of mateina (cafeina) were 1.20, 1.02 and 0.84. It is apparent that the higher the temperature above 80° C.



Figs. 2 and 3. Old methods of transporting and drying maté leaves.

the lower the percentage of alkaloids (mateina or cafeina).

According to Muello, the kind of wood used to supply the heat in a barbaqua has a marked effect on the flavor of the product that is obtained and used in preparing tea. Some of the most common species from which firewood is obtained in Misiones are as follows:

Ingá—*Inga edulis* Mart. (Leguminosae)
Timbó—*Enterolobium timboura* L. (Leguminosae)
Guatambú—*Balfourodendron viedelianum* L. (Rutaceae)
Petereby—*Cordia alliodora* R. and P. (Boraginaceae)
Ybirá pepé—*Holocalyx balansae* (Leguminosae)
Ybirá pytá—*Peltophorum dubium* L. (Leguminosae)
Lapacho—*Tecoma ipê* Mart. (Bignoniaceae)
Baacotinga—*Mimosa scabrella* Benthe (Leguminosae)
Eucalyptus—*Eucalyptus,* sp. (Myrtaceae)

All of these trees occur in Paraguay and Brazil and no doubt are likewise used there as a source of firewood for barbaquas. The average amount of wood utilized in the quick drying and toasting processes is about ten kilograms per kilogram of yerba maté. For this reason it is important to have access to trees that grow rapidly in order to have an adequate supply of wood. Mimosa is one of the most rapidly growing trees of the preceding list and is widely distributed. It is extensively used in the curing operation.

After treatment in the barbaqua the maté is further processed in a " canchadora " which is a circular table of wood boxed around the outer edge with boards. In the center of the table is an upright post with a longitudinal slot that receives the small end of a truncated cone into which are driven wooden pins or spikes. The outer end of the cone is just inside the boxed edge of the table. As this cone is pulled at the outer end of the axis it revolves and grinds the maté leaves to fine particles or to powder. A horse is commonly used to pull the cone, travelling in a circle around the table. At the end of this process the product is sacked and either sold for local consumption or sent to a mill where it is further treated and classified for commercial distribution.

A commercial maté mill or factory usually obtains the product from local dealers or buyers in a district. These buyers may operate a store where various products are handled for sale to the people of the area. When the crude maté arrives at the mill it undergoes a rigorous process of cleaning and grading. Soil, sticks and other impurities are removed, and the product is then passed through an oven or kiln supplied with indirect heat to remove any excess moisture. Later the product is put through a mill equipped with screens and sieves of different sizes which classify the ingredients in much the same way as seed is cleaned and graded. The grades are fine leaves, coarse particles of leaves, powder, leaf midribs, petioles and small-sized twigs. The classification and subsequent mixing of grades are made according to market demands. A special machine is used to completely pulverize any one grade or an unclassified product. The Uruguayan market demands a mixture of leaves and powder, whereas the Chilean market (first grade) prefers a product that consists only of leaves relatively free from powder. Furthermore, each type may be prepared as first and second grade, according to demand by the buyers. The second grade for Chile consists of coarse leaves, powder and leaf veins.

Maté may be prepared for final sale as green (untoasted) or toasted. Toasting is done in a rotating cylinder so placed that the maté comes in direct contact with a flame for a short time. The toasting process is a delicate opera-

FIG. 4. Removing maté leaves from a barbaqua, or modern drying apparatus.

tion because the subsequent flavor is determined by the temperature and the time of exposure. A temperature of 75° to 80° C. for one or two minutes is considered best.

Several methods of packing for sale are used in Brazil in a modern factory, such as was visited by the author in Curitiba in the State of Paraná. Shipments to Uruguay are made in barrels and paper sacks. Another method of packing is in cellophane packages, each containing one kilogram. These are packed 40 to the box. Shipments to northern Brazil and for export to Europe consist mainly of these boxes. One factory in Curitiba packs 220 such boxes per day with the machinery at present in use in addition to all other methods of packing. A third method is in cellophane paper packages with a net weight of 350 grams, each of which is then placed in a small wooden box. Sixty of these are placed in one large box. In 1947 the factory referred to above shipped 38,000 of these larger boxes. The maté in kilogram or 350-gram packages may be either toasted or untoasted, according to the demand. Toasted maté goes to São Paulo and Rio and some to the United States. Argentina buys the raw product in sacks from both Brazil and Paraguay and does all the processing within the country. Since Argentina buys the entire Paraguayan exportation the methods of processing used in Paraguay are less complicated than in Brazil whose shipments go to many parts of the world. The Paraguayan product is shipped mostly in large burlap sacks. All the wooden containers used in the factories of Curitiba are made of Paraná pine (*Araucaria brasiliensis* L.). Barrels and boxes of all sizes are made in the maté factories.

Production and Consumption

The yield of maté leaves per tree varies with age and the frequency of cutting. Under cultivated or good natural conditions the cutting may start with three-year-old trees when they are one and a half to two meters high. The yield per tree is then one-half to one and a half kilograms of cured and marketable leaves. Seven-year-old trees produce two to five kilograms, ten-year-old trees produce about eight kilograms per cut, and trees 20 to 35 years old yield 30 to 40 kilograms. As previously mentioned, the best practice is to cut a given tree every three or four years.

According to Azara, Paraguay in 1726 consumed and exported a total of 625 metric tons, and by 1786 the amount had increased to 2,500 tons. The exportation in the latter year was 600 tons to Peru, 300 tons to Chile, 50 tons to Bolivia and 250 tons to Rio da Prata (Argentina). By 1914 the Paraguayan production had more than trebled. The data for four years are as follows:

	Production	Exportation	Consumption
	Tons	*Tons*	*Tons*
1914	8,640	3.332	5,308
1918	9,857 *	3,707	6,410
1922	6,776 *	5,186	2,115
1923	11,267	5,118	6,149

* Apparently incorrect—Data from Martins.

Data on Brazilian production of maté in the early years of the industry have not been obtained, but the consumption was 2,500 in 1840, 9,500 in 1870, 14,000 in 1880 and 20,000 tons in 1882. In 1913 the production, consumption and exportation in metric tons by States, as given by Martins, were as follows:

State	Production	Consumption	Exportation
Paraná	50,918	5,000	45,918
Santa Catarina .	9,793	4,000	5,793
Rio Grande do Sul	18,414	12,000	6,414
Mato Grosso ...	7,512	1,500	6,012
Totals	86,637	22,500	64,137

In 1923 the estimates for Brazil were 117,649 tons produced, 87,649 exported and 30,000 consumed. Brazilian exports for five different years beginning in 1906 are given by Martins as follows:

		Tons by Country		
Year	Total tons	Argentina	Uruguay	Others
1906	57,796	43,109	12,836	1,851
1910	59,360	43,779	11,730	3,851
1914	59,707	44,574	12,736	2,397
1918	72,981	51,517	17,852	3,612
1922	82,367	52,073	26,061	4,233

The State of Paraná produces and exports more than any other Brazilian State. Exportations began in 1837; by 1906 the amount was 24,900 metric tons and this figure increased to 46,780 tons in 1922. In the 1923–24 fiscal year Paraná exported as follows, by countries:

Argentina	43,745,676	kilograms
Uruguay	13,107,521	"
Chile	959,163	"
Italy	63,170	"
Germany	10,687	"
United States	2,294	"
	57,888,511	kilograms

Production of maté in Argentina is confined almost entirely to the Misiones area which is contiguous to both Paraguay and Brazil. Consumption for the country as a whole has always exceeded production, which accounts for the importation from its neighbors. In 1910 there were 809,750 wild trees and 90,250 in cultivation, but three years later there were 700,769 wild trees and 279,416 in cultivation. In 1920–21 there were 5,376 hectares of land on which maté trees were cultivated. It is thus evident that Argentina is the only country of South America in which the maté tree is cultivated. Production and importation in 1920 in metric tons were: from cultivated trees, 1,200 tons; from wild trees, 800 tons; imported from Brazil, 82,367 tons; and from Paraguay, 6,500 tons. Muello gives data for 1943 as follows:

Production	Importation		Consumption
79,956 tons	Brazil	22,127 tons	109,757 tons
	Paraguay	6,214 tons	

Misiones in Argentina produces 80,000 tons. There are 8,800 producers who have 58,000,000 trees on 65,000 hectares. This area could produce 170,000 to 190,000 tons.

The estimated production in the three major producing countries at present, as given to the writer by Ivo Leão, one of the major producers in Curitiba, Paraná, is:

Brazil	76,000 tons	
Paraguay	6,000 tons	(exported, not total)
Argentina	120,000 tons	

This total production is in excess of 200,000 tons. Of Brazil's total production, approximately 59,000 tons are exported, of which 25,000 go to Argentina and 10,000 to Chile. It is estimated that consumption of maté annually in Argentina and Uruguay is ten kilograms per capita. The Brazilian Bulletin, published by the Brazilian Government Trade Bureau, 551 Fifth Ave., New York, for July 1, 1948, states that in 1946 and 1947 the total tons of maté exported were 50,104 and 54,534, respectively. The issue for January 1, 1949, gave the total Brazilian production for 1947 as about 70,000 tons.

Brazil has approximately 22,700 producers of maté, and Paraguay has about 11,660. There are many small and large factories in Brazil, the largest being in Curitiba, Paraná. Paraná has 24 factories, Rio Grande do Sul 43, Santa Catarina eight and Mato Grosso three. The annual output from the factories in Curitiba is 24,000 tons, and facilities are available there for doubling the production if the market demands it. At pres-

ent Brazil is the principal exporter of maté.

Cultivation

Inasmuch as Argentina consumes more maté than she produces, an effort is made to increase production there by planting and cultivating the trees.

Seeds of maté mature irregularly, beginning at the end of January and continuing until March. If freshly harvested fruits are placed in water, the pulp gradually softens and the seeds can be separated from it by washing. Moist seeds can be planted at once or allowed to dry first. According to Muello, Doctor Victor Garin, in the School of Agriculture at Posados in Misiones, tried several methods of treating seeds, such as stratification, fermentation, soaking in sulfuric or hydrochloric acid and heating for five, ten, 15 and 20 days at 40° C. He obtained percentages of germination ranging from 18 to 73. The length of time required was 60 to 284 days, the latter with dry seeds. Germination of seeds from fermented fruits occurred in 60 to 70 days, and stratification was not found necessary, in spite of the hard seed coats. Freshly harvested seeds are preferred.

FIG. 5. A simple cylindrical "sapecadora" for quick drying of maté leaves.

Moist seeds may be planted directly in raised beds in March or April. The common size of the beds is 50 by 120 centimeters. If forest soil with humus is available, that is considered best, but if old soils are needed it is necesary to add an abundance of humus and even chemical fertilizers. It is recommended to plant 180 to 200 grams of moist seed per square meter, which can be obtained from one and one-half kilograms of

FIGS. 6 and 7. Making and heading barrels of Paraná pine for maté.

green fruits. A kilogram of dry seed contains about 130,000 seeds. Irrigation is essential, and the beds must be covered with leaves or straw to prevent baking or hardening of the surface soil.

When the seedlings have developed four to eight leaves, they can be carefully removed, placed in boxes with soil around the roots and transplanted in larger beds that can be covered or shaded when necessary. Rich soil is needed, and water for irrigation should be near at hand. If the transplanting is done in November and December in Misiones there is usually abundant rainfall to assist in the establishment of the seedlings. The beds are usually one and one-half meters in width, and the seedlings are set in rows 12 to 20 centimeters between them. It is possible to maintain 100,000 young seedling trees on 7,500 square meters. When the plants have been in these latter beds 20 to 22 months they can be transplanted again to the permanent location. The trees are set in rows three to four meters between them and between trees in the row. Thus one hectare accommodates 800 to 1000 trees. Leaves may be harvested from trees three to five years of age, depending on the variety and on the fertility of the soil.

Chemical Analyses of Leaves

Martins has reviewed the history of early efforts to determine the chemical substances contained in maté leaves. According to him, Stenhouse and Lloyd Bullock discovered the presence of cafeina simultaneously. The former extracted a crystalline substance which he considered identical to cafeina. His first analysis showed 0.13 percent, but in 1854 his results gave between 1.1 and 1.23 percent. Rachelder in 1848 investigated the acid of maté and considered it identical to that of coffee. Peckolt in 1868 found 1.67 percent of cafein in the leaves of *Ilex paraguariensis*. Bijasson in 1876 named the principal alkaloid of maté, " matein ", and Moreau de Tours in 1904 confirmed Bijasson's results. The latter found that cafeina (= caffein) was 45.55 percent soluble in hot water, and mateina was 92.45 percent soluble. In chloroform the respective percentages of solubility were 19.02 and 27.29. Cafeina was 19.48 percent soluble in carbon tetrachloride and mateina was insoluble. His microscopic examination showed that cafein crystallized in regular needles and matein in small prisms. The chemical formulas given by him were: cafeina, $C_8H_{10}N_4O_2$; and mateina, $C_8H_{11}N_3O_4$. Peckolt, Macquaire and Lohman considered the principal alkaloid of maté as identical to that of coffee, tea, guaraná and kola.

Other substances found in maté leaves by these several chemists were essential oils, resins, albuminoids, gums, inorganic salts, cellulose and chlorophyll. Analysis of the ash of maté leaves gave phosphorus, carbon, sodium, potassium, calcium, magnesium, manganese, iron and silicon.

In Argentina, Corrado analyzed maté leaves from many sources, and the average percentages of several substances found by him are as follows:

	Percent
Water	8.92
Ash	6.07
Substances soluble in petroleum ether	5.29
Substances soluble in absolute alcohol	7.48
Substances soluble in distilled water	30.48
Tannin	1.657
Cafein (Matein)	0.82
Ash soluble in water	2.50
Ash insoluble in water	3.568
Sulfuric acid	0.295
Phosphoric acid (P_2O_5)	0.443
Iron oxide (F_2O_3)	0.108
Manganese oxide (Mn_2O_3)	0.097

Another Argentine chemist, La Valle, analyzed different grades of maté and found the percentage of matein to be 1.59 in green leaves with 10% moisture, 0.96 percent in petioles and midribs with 10% moisture, 1.08 in a mixture of leaves and petioles from cultivated trees, and only 0.62 percent in green fresh leaves from trees in the botanical garden in Buenos Aires.

In the "Transcritos da Revista Brasileira de Quimica" for September, 1947, data on the analysis of maté leaves by the laboratory of Fredric Damrau in New York are given as follows:

	Percent
Moisture	5.50
Resin	4.80
Crube fibre	17.68
Volatile oil	0.30
Total ash	4.25
Ash—water soluble	1.90
" —insoluble in water	2.35
" —acid soluble	4.12
" —insoluble in acid	0.13
Nitrogen	3.00
Tannin	12.40
Cafein	1.20
Theophyllin	0.05
Chlorophyll	1.90

The National Institute of Maté in Brazil analyzed dry maté leaves from Paraná and reported 9.05 percent tannin and 1.17 percent cafein (tri-methylxanthin).

In the same issue of the "Transcritos da Revista Brasileira de Quimica" referred to previously, a report is given from the Eddy Laboratory of New York showing the presence of vitamins A, B_1, B_2 and C. In 1944 the National Institute of Nutrition in Buenos Aires published the vitamin values in 100 grams of leaves based on 13 determinations. The data given are as follows:

Carotin	1.234	mg.
Vitamin A	2,095	International Units
Vitamin B_1	222.7	" "
Riboflavin	404.3	" "
Ascorbic acid	11.9	mg.
Nicotinic acid	6.92	mg.

Value and Methods of Preparing Maté

Tradition, custom and superstition have been important factors in determining the consumption of maté in South America. In areas where coffee is not grown, maté consumption is highest among the farmers and laborers. In the States of São Paulo and Minas Gerais, and in northern Paraná in Brazil where coffee production is concentrated, the common people drink coffee principally. Maté is available in tea houses in the large cities, but its consumption is relatively unimportant. The area covered by Rio Grande do Sul, southern Paraná, Santa Catarina and Mato Grosso in Brazil, and by Paraguay, Uruguay and Argentina includes the region of highest maté consumption, although the people in northeastern Brazil also drink maté.

Muello states that yerba maté is considered as a laxative and diuretic, as a purifier of the blood, a solvent of uric acid, an eliminator of toxins that accumulate from bad digestion of food, and is recommended for use by arthritics. Those who use maté habitually are inclined to increase the amount consumed because it gives a feeling of happiness and well being. The Argentine naturalist, Juan B. Ambrosetti who visited Paraguay in 1893, concluded that the workers with maté possessed unusual resistance to heat and insects and were happy and satisfied to work under very poor conditions without thought of rebellion. Such a reaction suggests that maté has the effect of a mild drug.

In Asuncion, Paraguay, the workers in a maté mill in 1946 were observed to be strong and able to do heavy physical work handling the sacks of maté. For breakfast they eat little and work all day in the mill with no food other than maté taken as a drink. It is reported that Paraguayan soldiers in the war with Brazil, Uruguay and Argentina, and later with Bolivia, often had no food other

than maté, yet they were able to undergo severe hardships in transporting military supplies over poor roads or no roads at all and in the fighting to which they were subjected. It may well be that the value of maté lies in the vitamins which recent analyses have disclosed. At any rate, the long and continued use of maté by millions of South Americans is probably due to something more than tradition or superstition.

FIG. 8. Machine and operator with small Paraná pine boxes of maté.

Maté is prepared principally by boiling the leaves in water for a short time, using about 50 grams of leaves per liter of water. After boiling for a few minutes, the pot is removed from the stove to allow the leaves to settle, and the maté is then served with sugar added to suit the taste. This is called " maté cocido ". The leaves may also be placed in a cloth bag that is immersed in boiling water, or the leaves can be placed in a coffee percolator and prepared as is coffee.

Another preparation is to pour boiling water on the leaves as is done with Chinese or Indian tea. For this purpose a teapot is used. This preparation is called " Té de Yerba ". Hot milk may be substituted for water in preparing maté to which the name " maté de leche " is then applied. " Maté con leche " implies that milk is added to the maté as is done with coffee. A common breakfast in areas where maté is regularly used consists of bread or biscuits with maté and milk.

Cold instead of hot water is commonly used among the native Paraguayans to prepare maté. This is especially preferred in tropical zones where there is excessive heat. For this preparation 40 grams are added to each liter of water in a teapot or a gourd (caá). The leaves may be

macerated and left in the water for 15 minutes; then the drink is served with or without sugar. Maté made with cold water is really not sanitary because of the manner in which the leaves are handled during the processing period.

Maté decoction is used in making ice cream, serving as a flavor. In the same way it is used to flavor cakes and other pastries.

A more recent method of preparation that was demonstrated to the writer in Curitiba, Paraná, by Sr. Ivo Leão is to prepare the maté first either as " cocido " or " té ", then cool the liquid, add lemon juice and sugar, and place in a refrigerator to be used when desired. This particular drink had a very pleasant flavor and no doubt would appeal to North Americans in the same way as the numerous other soft drinks that are available, or as iced tea or iced coffee.

The most common method of drinking maté is through a " bombilla " which is a metal tube with a perforated spatula at the base through which the liquid is sucked to the mouth. The container most commonly used is a cup made from the fruit of a gourd with a small mouth. In restaurants and cafés it is served in the same manner as Chinese tea.

Acknowledgments

The writer is grateful to Sr. Ivo Leão for the loan of photographs and for much information that was furnished by him in his factory at Curitiba, Paraná. Unfortunately it was not possible to review personally all the papers cited in the bibliography. The list is by no means complete, and only a few pertinent titles were selected in case readers wish to consult them for more detailed information.

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The Taxonomy, Genetics, Production and Uses of the Cultivated Species of *Cucurbita*

Hundreds of varieties in the five recognized species of this genus, all native to the Americas, are the sources of the well known pumpkins and squashes, of which about 150,000 tons, fresh weight, in 48½ million No. 2 cans, is the annual canned pack alone in the United States. The seeds constitute a potential but so far wholly undeveloped source of valuable oil.

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Historical Interest

Species of *Cucurbita* are among the most ancient of cultivated plants in the Americas. Bird's (8) discoveries at Huaca Prieta in the Chicama Valley of Peru have produced seed remnants and peduncles of *C. ficifolia* stratified at preceramic, pre-maize levels. This species was evidently cultivated by the farmers of that period, conservatively estimated at about 2000 B.C. The five commonly cultivated species have not been found in the wild state, but are invariably associated with man. This fact and the abundant materials of these species in the ruins of ancient civilizations indicate their importance in the development of primitive agriculture in the Americas.

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[2] The opportunity is taken here to express our thanks to the several investigators who have aided by personal discussions in formulating the opinions contained herein, especially to Professor Carl O. Sauer of the University of California for helpful suggestions and encouragement and for collections of *Cucurbita* native in Mexico and elsewhere; and to Mr. Grady A. Sanderson, scientific aide, who furnished the photographs for the illustrations.

Economic and Scientific Value

In addition to their interest for archeology and agriculture, the cultivated species of *Cucurbita* have had a fascination for botanists of several disciplines, and for laymen. The marked variation in size, shape and coloration of the fruits interest the scientist and the amateur alike. The large size of the various organs contributes to their usefulness as tools for numerous studies. The systematist has learned many things about the origins and relationships of the cultivated species, but puzzling questions remain to be solved. The morphologist finds them well-suited to studies of structure and of the developmental relationships of cells and organs. For the physiologist they furnish excellent material to study turgor pressure, food transport and other problems. The geneticist and plant breeder see in them almost limitless variation in fruit characters and marked, but less obvious, variation in characters of the seeds and vegetative organs. The compatibility relationships, both intraspecific and interspecific, are especially intriguing to the plant breeder, geneticist, and cytologist, as well as to the systematist. Artists have used the hard-shelled, oddly shaped and variously colored fruits of certain

sorts, either unadorned or variously treated, in many ornamental designs and arrangements.

The cucurbitas have been important in the development of native agriculture in the Americas, whence their culture has spread to all of the continents. At present they make valuable contributions to the food resources of peoples of all races in both primitive and advanced cultures the world over.

Scientific Names *vs.* Culinary Names

The common names "squash" and "pumpkin" have been applied rather indiscriminately by horticulturists, seedsmen, growers and consumers to the fruits of the cultivated *Cucurbita* species. This has resulted in considerable confusion regarding several matters, including the ancient question, "Will squashes and pumpkins cross?" An attempt has been made to end this confusion by defining the term "pumpkin" to include fruits of all varieties of *C. Pepo* and *C. moschata* and restricting the word "squash" to fruits of *C. maxima* (**18**). It would seem to be more appropriate to assign to the culinary words definitions in agreement with their derivations as modified by current usage, rather than to attempt to incorporate them into botanical terminology.

According to Harris and Allen (**31**), "pumpkin" was derived from Latin to indicate the gourdlike fruit of a cucurbitaceous vine (*C. Pepo*) utilized when ripe as forage, as a table vegetable, or in pies. In England and Europe the term indicates also the large fruits of *C. maxima* that are similarly used. In the United States it may indicate also the fruits of *C. moschata* that are used in the same manner. Hence, current usage suggests that the term "pumpkin" should be defined as the edible fruit of any species of *Cucurbita* utilized when ripe as forage, as a table vegetable or in pies; flesh somewhat coarse and/or strongly flavored; hence not generally served as a baked vegetable.

Harris and Allen (**31**) state that the word "squash" was derived from a northeastern American Indian word to indicate a fruit, apparently *C. Pepo*, eaten raw or used immature. It is now employed to designate the forms of *C. Pepo* that are used immature, all baking varieties of *C. maxima* and the cushaw forms of *C. moschata* which are used mature. It is also used for certain newer varieties of *C. Pepo* (*e.g.*, Table Queen) and of *C. moschata* (*e.g.*, Butternut) that are used mature. Current usage suggests that the term "summer squash" should be defined as the edible fruit of any species of *Cucurbita*, commonly *C. Pepo*, utilized when immature as a table vegetable. Similarly, "winter squash" should be defined as the edible fruit of any species of *Cucurbita* utilized when ripe as feed for livestock, as a table vegetable or in pies; flesh usually fine-grained and of mild flavor, hence suitable for baking.

The terms so defined have no implications regarding the botanical species and need not be used in that sense. Obviously the question "do squashes and pumpkins cross?" is meaningless. More exact terms must be used in discussions of breeding behavior. The words "maxima", "pepo", "moschata", "mixta" and "ficifolia" can be used as common names of the botanical species where such usage is desired, as has been suggested by Tapley *et al.* (**52**).

Uses

In the present-day agriculture in this country the cultivated forms of *Cucurbita* have three principal uses: (*a*) consumed in the immature state as a fresh vegetable, either stewed, boiled or fried; (*b*) used in the mature state for baking; (*c*) used in the mature state for canning, eventually to be used as pie-stock for the bakery trade.

The summer squashes from which the immature fruit is used as a fresh vegetable develop very rapidly and require only a short growing season. The fruits can be harvested within two to six days after anthesis of the female flower. Thus during the harvest season the vines are visited two or three times per week. Some markets prefer a more mature product. In this case harvest can be delayed until the skin resists mild pressure with the thumbnail. Winter squashes are harvested when mature and require a long growing season. They are usually prepared for table use by baking. Properly cured, this type of squash can be stored at about 55° F. and moderately high humidity up to six months without deteriorating seriously. The flesh of winter squashes is dried in strips by some peoples and used later in soups and stews.

Pumpkins are also harvested in the mature state and as a rule are canned or fed to livestock. According to Thompson (53), "The large-fruited and heavy-yielding varieties having yellow or light-colored rinds are the most desirable for canning. The green-skinned varieties are more difficult to handle so as to prevent discoloration of the canned product by green tissue that may be missed in removing the rind. To meet the requirements of the commercial canning trade a variety must be a heavy yielder, and the fruits must have flesh of the proper color and texture. Flavor is not an important factor in the selection of canning varieties as it can be controlled to some extent by the canner. Tests made in using different varieties for pie-making show that the flavor is so influenced by spices and other ingredients that the original flavor is not very important where the product is used for pies".

There are several minor uses which are of interest. Many of the field pumpkins are extensively employed as stock feed. In some of the Latin American countries and in Asia *Cucurbita* seeds are roasted and sold in the markets, much as peanuts are in this country. A special use is beginning to be adopted to a certain extent in this country where "naked seeded" varieties of *C. Pepo* are fried in deep fat, salted and sold in small packages by some specialty dealers.

The possibility of using the seeds of *Cucurbita* as sources of vegetable fats and proteins has not been exploited with the vigor that its potential importance deserves. The Russian scientists have given some consideration to the possibility of using them as a source of oil. Pangalo (42) reports that seeds of *C. Pepo*, *C. moschata* and *C. maxima* contain an average of 45 percent oil. Evidently the small-fruited varieties of *C. Pepo* give the greatest promise as oil producers because of the large number of fruits per plant, with relatively immense quantities of seed. Recently Curtis (25) has given this problem some attention. His figures indicate that the seeds of *C. Pepo* compare favorably with shelled peanuts in the percentage of fat and protein which they contain, while the naked-seeded mutant of *C. Pepo* exceeds peanuts in the percentage content of both fats and oils. The yield of seed of *C. Pepo* ranges from 300 to 1200 pounds per acre, calculated on the basis of very limited data. Two comparable crops, soybeans and shelled peanuts, yield about 1200 and 1500 pounds per acre, respectively. Apparently a valuable domestic source of vegetable oil and protein is being neglected when seeds of *Cucurbita* species are left unutilized.

In certain Latin American countries the flesh of *C. ficifolia* is candied and eaten as a confection. The flesh may also be fermented to make an alcoholic beverage.

In recent years there has been much interest in the gourd varieties of *C. Pepo*, particularly among garden clubs and home gardeners. Two rather successful

organizations have been formed to exploit the decorative and ornamental value of these fruits. Many gourds of this group make exceedingly attractive decorations, and many colorful arrangements can be devised. Those that are naturally colored are usually used unchanged, whereas the solid colored forms are commonly decorated (**3, 34**).

Food Value

In their important studies of the comparative values of California fresh vegetables, MacGillivray *et al* (**36–39**) have placed winter squash (the baking types) in Group I which includes the most efficient vegetable crops, evaluated on a pound, acre, and man-hour basis. On the other hand, summer squash (those types used for food in the immature state) are found in the lowest category, Group IV. Winter squash is harvested only once, and the labor needed to produce and harvest the crop is comparatively small. For this reason the crop rates high in the quantity of nutrients produced per man-hour. MacGillivray *et al* state that the food value of mature pumpkins, which are used primarily for pie-stock, is about the same as that of winter squash. Table I conveys some idea of the relative food values of winter squash and summer squash.

TABLE I

YIELD, EDIBLE PORTION AND FOOD CONSTITUENTS IN POUNDS PER ACRE OF WINTER SQUASH AND SUMMER SQUASH (**36–39**)

Crop	Average yield (pounds)	Edible portion (pounds)	Protein (pounds)	Calcium (pounds)	Iron (pounds)	Calories (thousands)	Vitamins			
							C (grams)	B_1 (grams)	G (grams)	A (millions of International units)
Summer squash	9,750	9,457	56.7	1.4187	0.0378	804	132	2.06	3.48	128.80
Winter squash	17,000	12,580	188.7	2.3902	0.0755	2,516	176	2.74	4.63	171.34

Storage, Processing and Composition

A considerable body of data has been accumulated regarding the composition of *Cucurbita* varieties with relation to the canned product and to their direct culinary use. Doty *et al* (**26**) have made a four-year study, designed to show what effect variety, degree of maturity, and chemical composition have upon the consistency (stiffness) of the canned product. Within certain limits the variety used did not appear to be nearly so important as several environmental factors which can and should be carefully controlled by the processor. First, fruits from all varieties produce a pack of higher consistency if they are canned when slightly immature or barely ripe. Second, starch and solids content in all varieties tested reaches a maximum at about the same time the fruit yields a pack of maximum consistency. This tends to indicate that starch and solids, especially soluble solids, are major factors affecting consistency of the canned product. Third, the consistency of the canned product can be increased considerably by blending the flesh of high consistency varieties with that of low consistency varieties. Fourth, fruits that are to be processed by canners should not be stored. Solids, particularly starch, decrease rapidly in storage

with a correlated decrease in the consistency of the canned material. However, Yeager *et al* (65) concluded from actual canning tests that Hubbard squashes should be stored for about three months (at 50° to 60° F. and relative humidity of 20 to 50 percent) before processing.

In an elaborate study of the differences in the compositon of the fruits of eight varieties of *Cucurbita Pepo,* six of *C. moschata* and 22 of *C. maxima* over a period of one to four years, Culpepper and Moon (21) have produced a reliable picture of the changes that take place in the fruits of the various varieties from ten days up to 165 days after anthesis. Some of their more important conclusions are: (*a*) mean total-solids content (expressed as percentage of fresh weight) decreased during the first ten days of growth and then increased up to the 40-day stage, after which there was a gradual decline; (*b*) sugars increased during the developmental period and the first 60 days in storage; (*c*) acid-hydrolyzable polysaccharides increased rapidly up to the 30- to 40-day stage and then quickly decreased to the 90-day stage, after which there was a slow decline; (*d*) although the changes were not important, acidity, astringency and total nitrogen content decreased slowly to the ten- to 20-day stage and then increased slowly to the end of the storage period; (*e*) the nitrate nitrogen increased up to the 20-day stage and then declined to the end of the storage period.

In summing up their observations Culpepper and Moon arrived at the following generalization: " When the results for each constituent for all stages of maturity in all years were averaged it was found that in general the varieties markedly high in sugar were also markedly high in acid-hydrolyzable polysaccharides; that those high in total solids were high in soluble solids and only moderately high in total nitrogen ". They conclude with the statement quoted below, which might well be given consideration by the amateur gardener or even the experienced vegetable grower in selecting a variety of *Cucurbita* for his particular needs: " Differences in the flavor, consistency, and appearance of *Cucurbita* varieties were often very great and were directly related to differences in compositon. Because of these differences some varieties that are excellent for one purpose may be only mediocre for another. The period when *Cucurbita* fruits have maximum value depends upon the variety and the particular use to be made of the fruits. Some varieties are excellent for certain culinary uses during the early stages of maturity and very poor for the same uses at later stages, while the reverse may be true of other varieties ".

Phillips (45) in a later study has investigated changes in the composition of squash during storage. Although not strictly comparable, because of different varieties and differences in methods of calculation, his results tend to confirm the observations of Culpepper and Moon.

Production

It is very difficult to obtain meaningful statistics for the production of squash and pumpkins because acreage and production figures for these crops are not reported on an annual basis in the U. S. Department of Agriculture's " Agricultural Statistics ". The only figures for these crops reported on an annual basis are those for the total canned pack. For the past 18 years the canned pack of squash and pumpkin has averaged 2,433,000 cases (24 No. 2 cans per case), or approximately 148,958 tons, fresh weight.

The commercial acreage and value for pumpkins and squash are reported separately in the Agricultural Census [3]. In

[3] We are indebted to Mr. J. E. Mullen, Statistician, Calif. Crop and Livestock Reporting Service, Sacramento, Calif., for his kindness in extracting this material from the Agricultural Census.

1939 the acreage of pumpkin for the United States amounted to 13,182 acres with a cash value of $320,833. For squash the acreage was 28,931 acres with a value of $1,744,729. Indiana was responsible for the largest acreage of pumpkin—4,380 acres; followed by Illinois—2,564 acres; and Maryland—1,163 acres. In the production of squash the leading States were: California—5,238 acres; Florida—3,819 acres; New York—2,205 acres; Texas—2,107 acres; and Michigan—1,500 acres. With the exception of California, Florida and Texas, where the summer squash types are produced throughout the year, squash and pumpkin production is centered in the northern tier of States, extending as far south as Maryland and through the mid-western States of Iowa and Minnesota. The winter squash types are adapted to these areas, and the cool weather of late summer and fall is conducive to high quality.

The importance of the cultivated species of *Cucurbita* in our agriculture can not be properly evaluated by figures obtained in a conventional census, since the small garden, the produce from which is consumed on the premises, is not taken into account. It is well known that almost every vegetable gardener plants at least one variety of *Cucurbita*. Furthermore, the extensive acreage interplanted with corn and usually disposed of as stock feed is not reported. For these reasons the members of this group are far more important in our economy than the production figures would seem to imply.

Taxonomy

Five species of *Cucurbita* are cultivated for food, forage or ornamental purposes. They are: *C. Pepo* L., *C. moschata* Duch., *C. mixta* Pang., *C. maxima* Duch. and *C. ficifolia* Bouché. *C. ficifolia* has not ordinarily been considered a domesticate. However, the observations of Bukasov (10) and recent collections by C. O. Sauer, Robert West and others (unpublished information) indicate that this species has had a long history of cultivation in the highlands of Mexico, Central America and South America. The fruits and seeds of still other species of *Cucurbita* were used by the American aborigines for food purposes, but apparently none of them was cultivated to an appreciable extent. The five species named above have had long histories as important cultigens in ancient American civilizations and, after contact, in nearly all parts of the world.

Bailey (2) and Tapley *et al.* (52) have reviewed the taxonomy of the cultivated species of *Cucurbita*. Later Bailey (4, 5) has monographed the wild species. Pangalo (43) described a new species, *C. mixta,* from material collected in Mexico and Central America. From the brief description of this species written in English and from the photographs it seems likely that certain American horticultural varieties belong in this category. These varieties, heretofore included in *C. moschata* or elsewhere by American authors, are included in *C. mixta* by the present authors. This species was also represented in a collection of *Cucurbita* obtained from the Taos Indian Village near Taos, New Mexico, by A. C. Hildreth of the U. S. Department of Agriculture. Bailey's (5) *C. argyrosperma* (= *C. mixta* var. *cyanoperizona* Pang.) apparently belongs here. The following characterizations of the five cultivated species have been compiled from the works cited above, supplemented by observational studies by the present authors.

Cucurbita Pepo L. Plant annual, frost-sensitive but tolerating cool temperatures, vine or bush, harsh, spiculate setose; stem hard, frequently five-angled; leaf cordate-ovate, serrate, deeply lobed with narrow, acute sinuses, with or without whitish blotches; staminate and

pistillate flowers acuminate in the bud, with short, awl-shaped sepals and bright yellow to orange-yellow corollas, the corolla lobes closed the evening before anthesis; androecium short, thick, conical; stigmas small, yellow, smooth; mature peduncle hard, sharply five-angled, without cork development, rounded, but moderately or not at all enlarged at the fruit attachment (Fig. 2); fruit a pepo (Fig. 1), variable in size, shape, color and other characters, hard- or soft-shelled, often dull-colored; fruit flesh moderately moist to dry, dark yellow-orange to white, coarse, tender to tough-fibered; placenta collapsing at maturity, moderately moist to dry, fibrous; seeds separating readily and cleanly from pulp; seed large or small, plump, ovate-ellipsoidal, with symmetrical, obtuse

FIG. 1. A fruit in a *Cucurbita Pepo* collection from Mexico, showing one of the many shapes and color patterns.

funicular attachment (Fig. 3); seed body pale tan to dingy white; seed margin smooth or rarely separating into threads (Fig. 3, *f*), obtuse, regular in outline, usually thin (Fig. 3, *a, c*), but greatly enlarged in some varieties (Fig. 3, *g*), like the body in color. Seed coat lacking in some varieties, the embryo then inclosed in the dark-green perisperm (Fig. 3, *d*).

Examples: Connecticut Field, Small Sugar, Tours, Table Queen, White Bush Scallop, Yellow Crookneck, Golden Custard, English Marrow, Zucchini, Orange Gourd, Tricolor Spoon Gourd.

Cucurbita moschata Duch. Plant annual, frost-sensitve and intolerant of cool temperature, vine, not harsh, soft pilose; stem moderately hard, round or smoothly five-angled; leaf large, broad-cordate to reniform, not lobed or shallowly lobed with broad, obtuse sinuses, with or less often without whitish blotches; flowers acuminate in the bud, the corolla lobes closed the evening before anthesis, with large flat, often foliaceous sepals and yellow to yellow-orange corollas; androecium usually long and slender, columnar; stigmas large, bright orange or green, rough; mature peduncle hard, smoothly five-angled, without cork development, rounded and moderately or more often greatly enlarged at the fruit attachment, frequently long and slender (Fig. 5); fruit a pepo (Fig. 4), variable but not hard-shelled, dull in color; fruit flesh moderately dry to moist, yellow to dark orange (white unknown), fine-

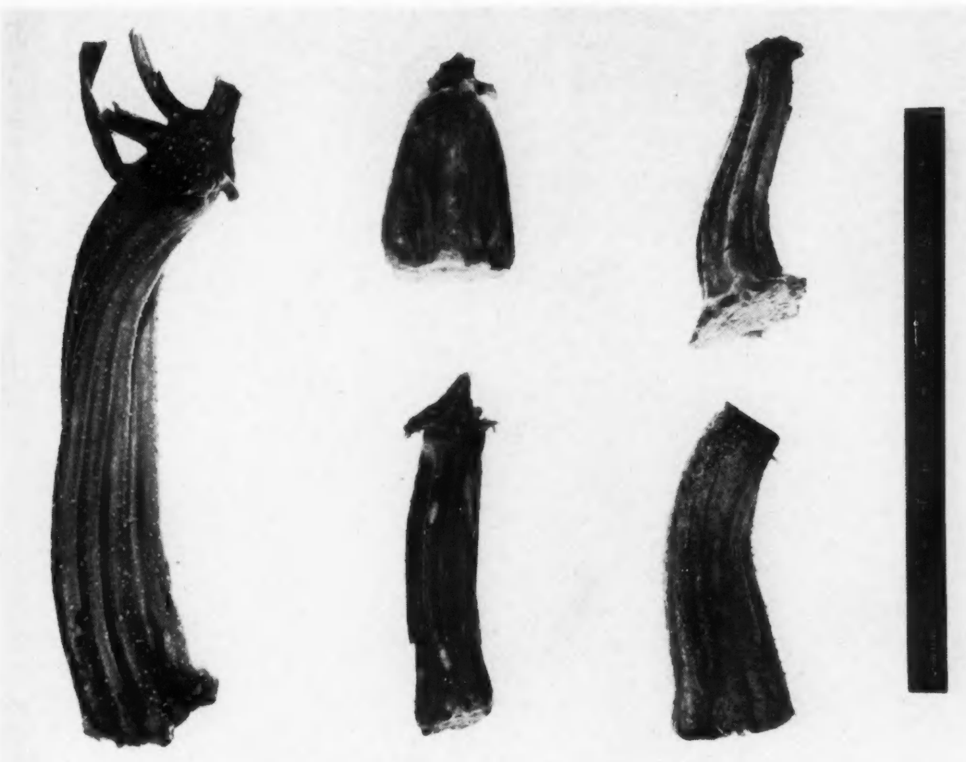

FIG. 2. Peduncles of five collections of *Cucurbita Pepo* from Mexico, showing their range in size and shape.

grained to coarse with gelatinous fibers; placenta collapsing at maturity, usually moist, soft fibrous; seeds separating or finely granular, rough, dingy white to dark brown; seed margin scalloped, separating in threads or threads adhering to-

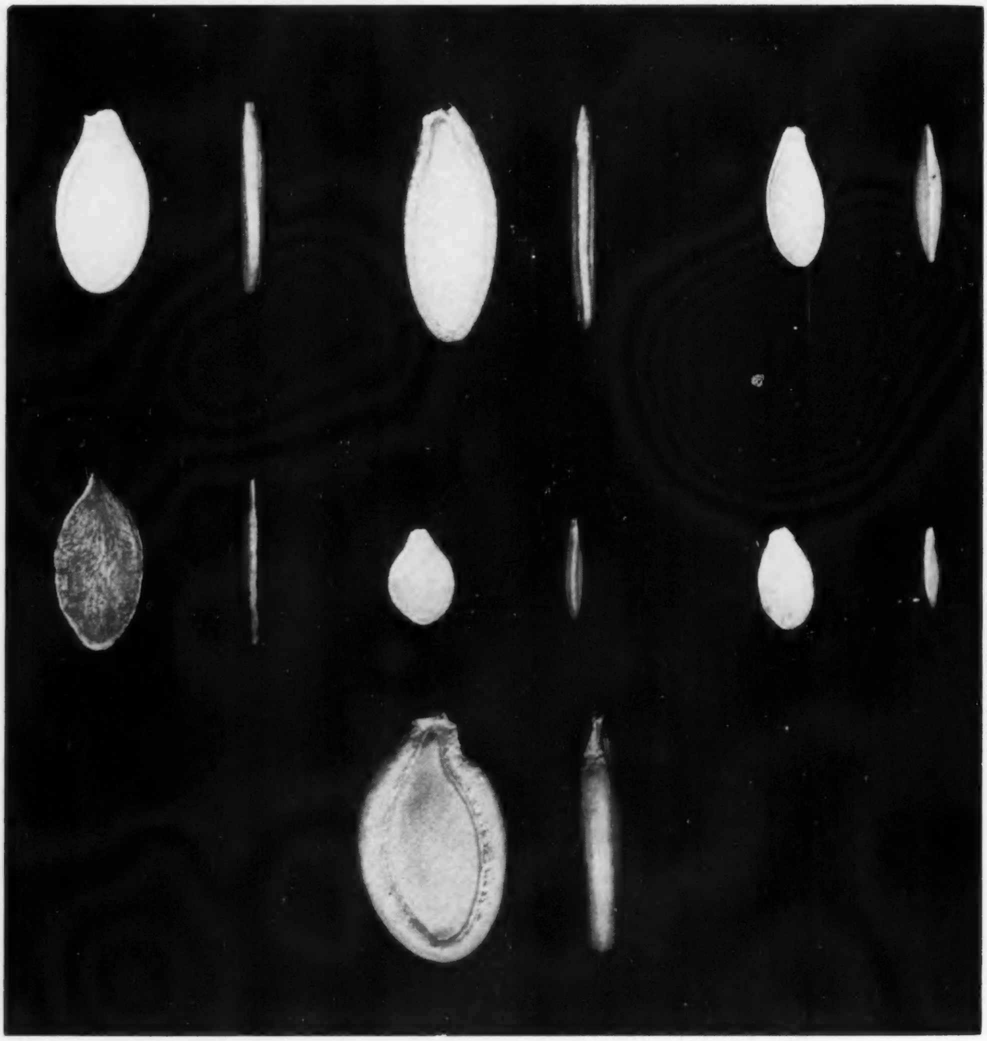

FIG. 3. Side and edge views of seeds in seven collections of *Cucurbita Pepo,* showing the range in size and shape: *a,* var. English Vegetable Marrow; *b* and *c,* from Mexico; *d,* naked seeded gourd; *e* and *f,* ornamental gourds; *g,* var. Tours. All × 1.5.
(Lettering of seeds in pairs begins with top row and runs from left to right)

readily and cleanly from pulp; seed plump or flat, ovate-ellipsoidal, with slightly asymmetrical, obtuse funicular attachment (Fig. 6); seed body smooth gether, obtuse, irregular in outline, thin or moderately thick, frequently darker colored than the body.

Examples: Chirimen, Sugar Marvel,

Turkish Honey, Kentucky Field, Dickinson, Golden Winter Crookneck, Butternut.

Cucurbita mixta Pang. Plant annual, frost-sensitive and intolerant of cool temperature, vine, pilose, not harsh; stem hard, five-angled; leaf large, broad cordate to cordate-ovate, shallowly to moderately lobed with broad, obtuse sinuses, with or rarely without whitish blotches; flowers acuminate in the bud, with long, linear sepals (not foliaceous) and yellow to yellow-orange corollas, the corolla lobes closed the evening before anthesis; androecium usually long and slender, columnar; stigmas large, bright yellow to orange or green, rough; mature peduncle hard, basically five-angled, rounded, but moderately or not at all enlarged at the fruit attachment, as in *Cucurbita Pepo* but not as in *C. moschata*, this structure being usually hidden by the formation of hard, warty cork that moderately or greatly increases the diameter of this organ, which is usually short and much thickened (Fig. **8**); fruit a pepo (Fig. **7**), variable, hard- or soft-shelled, usually dull in color; fruit flesh moderately dry (resembling *C. Pepo* but not *C. moschata*), white to pale tan or yellow (orange unknown), coarse-grained with soft but not gelatinous fibers; placenta collapsing at maturity, dry, soft-fibrous; seeds separating readily and cleanly from pulp; seed plump, ovate-ellipsoidal, with slightly asymmetrical or symmetrical, obtuse funicular attachment (Fig. **9**); seed body smooth or split open in various ("oriental") patterns (Fig. **9**, *a*) (never granular), white or tan-brown and then the seed coat thick (Fig. **9**, *d*, *e*); margin barely scalloped, separating into threads or threads adhering together, acute, barely irregular in

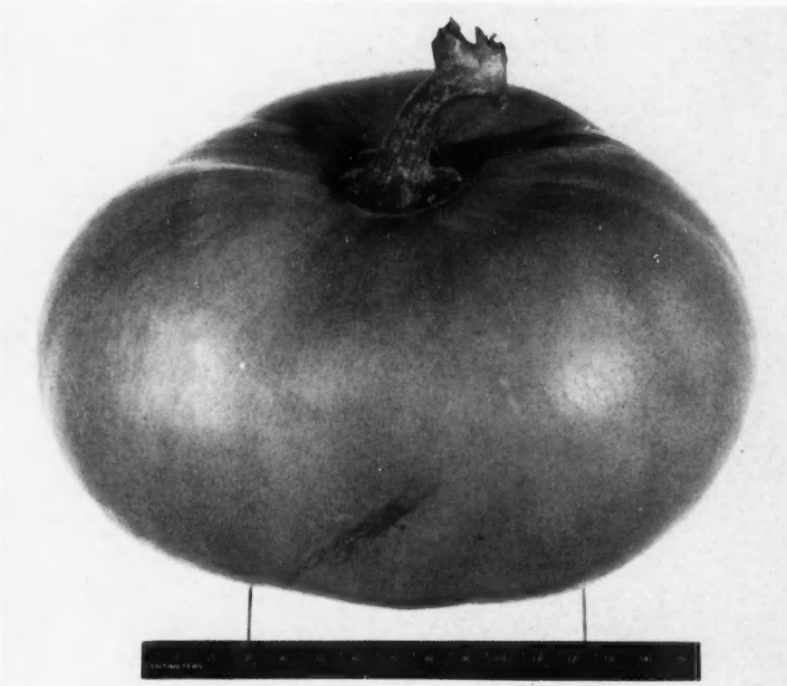

FIG. 4. A fruit of *Cucurbita moschata* var. Kentucky field.

outline, usually thin (Fig. 9, *a*), but very broad in some collections (Fig. 9, *f*), frequently darker colored than the body.

Examples: White Cushaw, Green-striped Cushaw, Tennessee Sweet Potato, Japanese Pie, Silverseed Gourd.

Cucurbita maxima Duch. Plant annual, frost-sensitive but tolerant of cool temperatures, vine or rarely bush, slightly harsh, moderately setose; stem soft, round in cross section; leaf reniform to cordate-reniform, serrate, not lobed or else shallowly lobed with broad, obtuse sinuses, with or more often without whitish blotches; flowers acute to obtuse in the bud, with moderately long, linear sepals and bright yellow corollas, the corolla lobes opening slightly the evening before anthesis; androecium short, thick, columnar; stigmas small, yellow, smooth; mature peduncle soft, round in cross section but becoming irregularly thickened with soft cork in most varieties, not rounded but adnate with the fruit, and not enlarged at the fruit attachment (Fig. 11); fruit a pepo (Fig. 10), the ovary protruding considerably from the receptacle in some varieties (turban), variable, soft- or hard-shelled, dull or brightly colored; fruit flesh moderately moist to dry, fine-grained (without distinct gelatinous, soft, or tough fibres), pale yellow to yellow tinged with orange (white and yellowish orange unknown); placenta collapsing at maturity, fleshy-fibrous, dry; seeds separating from pulp

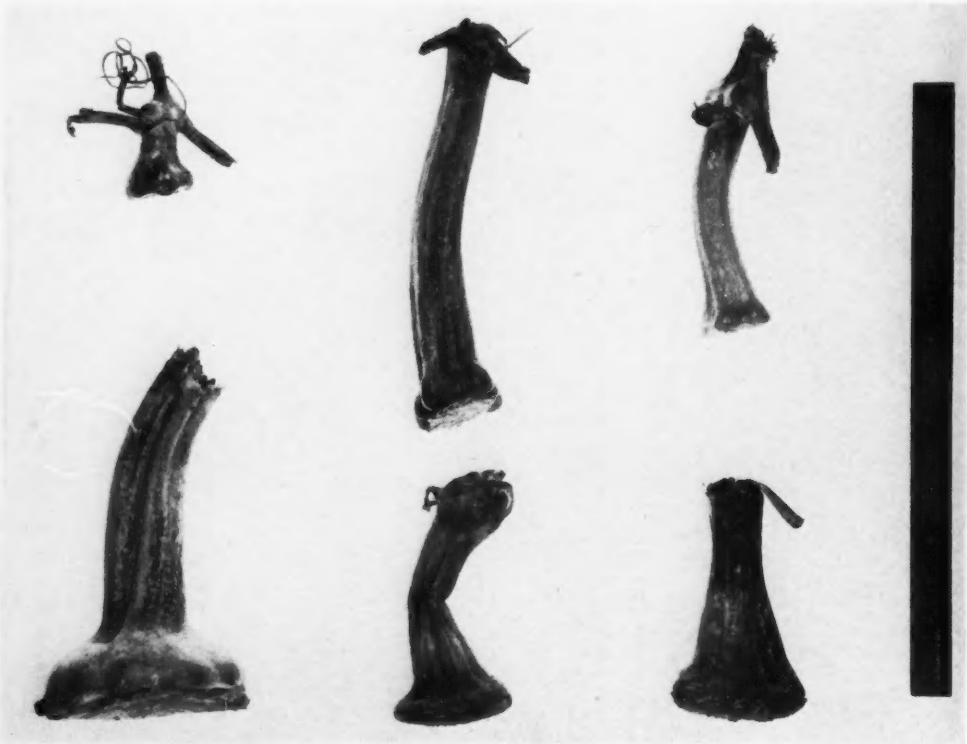

FIG. 5. Peduncles from six collections of *Cucurbita moschata: a*, var. Butternut; *b* and *c*, from Mexico; *d*, from an island in the South Pacific; *e* and *f*, from Mexico.
(Lettering begins with top row and runs from left to right)

with difficulty and not cleanly; seed plump, ovate-ellipsoidal, with acute, asymmetrical, funicular attachment (Fig. 12); seed body smooth or rarely finely striate or pitted, white (Fig. 12, *a, c, e*) or tan-brown and then the seed coat thick (Fig. 12, *b, d, f*); seed margin smooth, obtuse, regular in outline, thin to moderately thick, like the body or paler in color.

Examples: Mammoth, Mammoth Chili, Hubbard, Delicious, Boston Marrow, Banana, Buttercup, Essex Hybrid, Olive, Marblehead.

Cucurbita ficifolia Bouché. Plant perennial but not frost-hardy, tolerant of cool temperatures, vine, harsh, moderately spiculate-setose; stem hard, smoothly five-angled; leaf cordate, serrate, moderately lobed with narrow, obtuse sinuses, usually with whitish blotches; flowers obtuse in the bud, the corolla lobes closed the evening before anthesis, with small, linear sepals and bright yellow to light orange corollas; corolla tube short and broad at the base; corolla lobes short, obtuse; androecium short, thick, columnar; stigmas small, pale yellow, smooth; mature peduncle hard, round to smoothly five-angled, without cork development, not enlarged or only moderately enlarged at the fruit attachment with rounded margin not adnate with the fruit (Fig. 14); fruit a pepo (Fig. 13), globular to oblong, with hard shell, dull colored, white, ivory, or

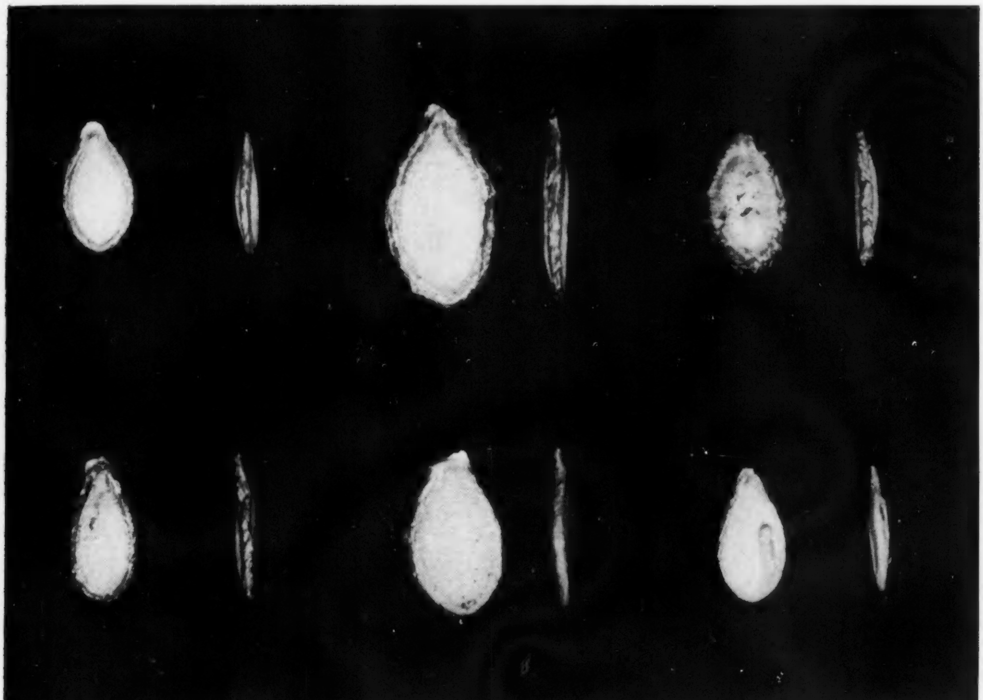

FIG. 6. Seeds of six collections of *Cucurbita moschata: a,* var. Butternut; *b* and *c,* from Mexico; *d,* var. Sugar Marvel; *e,* from South America; *f,* U. S. Dept. Agr. Plant Introduction No. 143292. All × 1.5.

(Lettering of seeds in pairs begins with top row and runs from left to right)

pale green, often with green markings; flesh coarse, tough, fibrous, moderately dry, white; placenta persistent, fleshy fibrous, moderately moist; seeds separating readily and cleanly from the pulp; seed usually flat (Fig. 15) ovate-ellipsoidal, with obtuse, slightly asymmetrical funicular attachment; seed body smooth or minutely pebbled, black (Fig. 15, *a, c, e*) or dingy white (Fig. 15, *b, d, f*); seed margin smooth, obtuse, regular in outline, thin to moderately thick, like the body in color.

Examples: Fig-leaf Gourd, Malabar Gourd, Lacayote, Silacayote.

FIG. 7. A fruit of *Cucurbita mixta* from Mexico.

Summary of Specific Differences

The cultivated species of *Cucurbita* are distinguished from one another by differences in many characters. The extreme variations found within the species make identification of unknown specimens difficult, especially if knowledge of certain characters is lacking. Many collections can be identified by the seed or the peduncle alone, and most collections can be identified from specimens of both of these organs.

Some collections are difficult to identify from single key characters, and often the desired organ is not available for

identification. Therefore, the more important key characters have been summarized in Table II.

Geographic Origin

The question of the geographic origin of the cultivated *Cucurbita* species has been a subject of early and sustained interest among botanists concerned with the origin and domestication of cultivated plants. At the present time the evidence is overwhelmingly in favor of an American origin of all five cultivated species. The basis for this conclusion has been assembled in an earlier paper (60). Some of the points covered are of interest for our present discussion. A careful investigation of the historical record indicates that the cultivated species of *Cucurbita* were unknown in western Europe prior to the discovery of America in **1492**. In the following century at least two species, *C. Pepo* and *C. maxima*, were recognized by the herbalists, and in *C. Pepo* a number of varieties were known. While not decisive, these pieces of evidence indicate that there must be some connection between the discovery of America in the late fifteenth century and the appearance of squashes and pumpkins in western Europe early in the sixteenth century.

TABLE II

TABULATION OF KEY CHARACTERS DIFFERENTIATING THE CULTIVATED SPECIES OF *Cucurbita*

Species		Organ						
		Seta	Stem	Androecium	Peduncle	Fruit flesh	Funicular attachment of seed	Seed margin
C. Pepo	annual	spiculate	hard, angular	short, thick, conical	hard, angular, ridged	coarse-grained	obtuse, symmetrical	smooth, obtuse
C. moschata	annual	lacking	moderately hard, smoothly angled	long, slender, columnar	hard, smoothly angular, flared	fine-grained or coarse with gelatinous fibers	obtuse, slightly asymmetrical	scalloped, obtuse
C. mixta	annual	lacking	hard, angular	long, slender, columnar	hard, basically angular, but enlarged by hard cork	coarse-grained	obtuse, slightly asymmetrical	barely scalloped, acute
C. maxima	annual	moderately spiculate	soft, round	short, thick, columnar	soft, basically round, but enlarged by soft cork	fine-grained	acute, asymmetrical	smooth, obtuse
C. ficifolia	perennial	moderately spiculate	hard, smoothly angled	short, thick, columnar	hard, smoothly angled, slightly flaring	coarse, tough-fibrous	obtuse, slightly asymmetrical	smooth, obtuse

The archeological record is even more convincing than the historical. In Table III we have recorded the well-documented finds of archeological material of the cultivated species of *Cucurbita*. This table is by no means complete, but

it does give a representative sample of the well-documented finds of archeological *Cucurbita* material. From the table it is quite evident that *C. Pepo* was restricted to North America. It is also clear from the reports of explorers and travelers that at the time of contact this species was localized in the eastern portion of the United States, extending about as far west as the Mississippi River, and in southeastern Canada. Recently the Russian plant explorers (10) have extended the pre-Columbian range of *C. Pepo* as far south as Costa Rica.

FIG. 8. Peduncles from six collections of *Cucurbita mixta*: *a* and *b*, from Mexico; *c*, var. Silverseed Gourd; *d, e* and *f*, from Mexico.
(Lettering begins with top row and runs from left to right)

Archeologically *Cucurbita moschata* had the most widespread distribution of the cultivated species. This statement is substantiated by evidence for its presence as early as Basket Maker II times in the American Southwest, a single record of occurrence in Central America and three records from Peru. According to the Russian plant explorers (10), *C. moschata* is of widespread occurrence in modern times. It is extensively cultivated in Mexico, the countries of Central America, Colombia in South America, and some of the islands of the West Indies. In Panama and Colombia it is the only annual species of *Cucurbita* under cultivation. Another interesting item uncovered by the Russians is the observation that forms of this species in

Mexico and Central America are characterized by white seeds, while to the south, in Panama and Colombia, brown-seeded forms are predominant. If our interpretation is correct, the white-seeded forms from Mexico and Central America are varieties of *C. mixta,* whereas the brown-seeded forms from Panama and Colombia belong to *C. moschata.* The archeological material of *C. moschata* needs critical reexamination. It is highly probable that some of the specimens recorded as this species are in reality *C. mixta.* Thus the apparently widespread pre-contact distribution of *C. moschata* may be accounted for in part by confusion with *C. mixta.*

Both archeologically and in its modern distribution *C. maxima* is evidently the most restricted member of the group. Archeological occurrence is limited to two records from Peru, and at the time of contact it was probably confined to the South American countries of Brazil, Argentina, Chile, Bolivia and Peru.

The meagre archeological record of *C. ficifolia* does not supply much information regarding the pre-contact distribution of this entity. About all we can say is that it was present in Peru and was probably one of the earliest of man's cultivated plants in the Americas. The Russians (10) report that *C. ficifolia* exceeds all of the other cultivated *Cucurbita* species in the extent of its present-day distribution. It has been found in all countries from Mexico, through Central America and the Andean countries

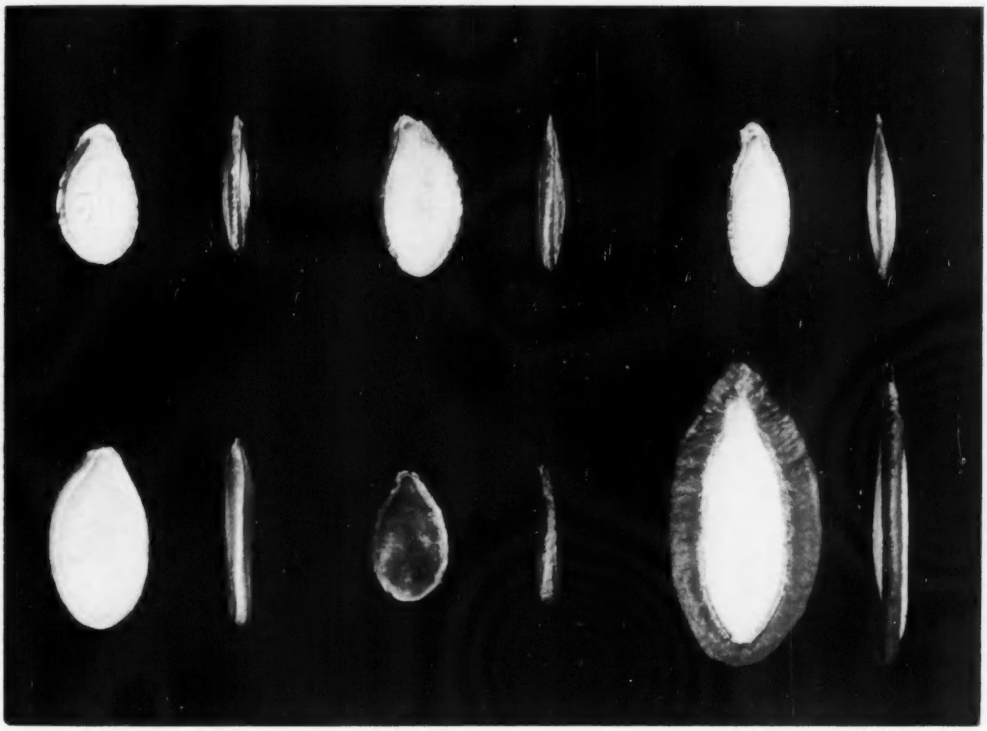

FIG. 9. Seeds in six collections of *Cucurbita mixta: a,* var. Japanese Pie; *b,* var. Tennessee Sweet Potato; *c,* from Mexico; *d,* from Taos Indian Village, New Mexico; *e,* from South America; *f,* var. Silverseed Gourd. All × 1.5.
(Lettering of seeds in pairs begins with top row and runs from left to right)

of South America, to Chile. Judged by its present distribution, it is the highland member of this assemblage.

Ecology

The ecological preferences of the five cultivated species of *Cucurbita* are not well understood, but there are a few facts that have been established by repeated observation. In tropical America *C. ficifolia* grows at higher elevations than the other species, which indicates that it is more tolerant of low temperatures; likewise it seems to require a short photoperiod for reproduction. With respect to temperature relationships among the annual species, *C. maxima* is the most tolerant of low temperature, *C. moschata* and *C. mixta* the least, with *C. Pepo* in an intermediate position. Yeager and Latzke (64) developed the Buttercup variety of *C. maxima* to serve as a substitute for the sweet potato in regions with climates too cool for the latter. The annual species are relatively insensitive to photoperiod. The cultivated species of *Cucurbita* are not very selective in their soil requirements. They can be cultured successfully on almost any good, well-drained garden soil, with a neutral or slightly acid reaction. These species are drought-tolerant and require

TABLE III [4]

ARCHEOLOGICAL RECORD OF THE CULTIVATED SPECIES OF *Cucurbita*

Species	Site	Culture period	Date	Investigator
		NORTH AMERICA		
C. Pepo	Medicine Cave, Arizona	Pueblo II	900–1050 A.D.	Bartlett (13)
	Ridge Ruin, Arizona	Pueblo II	900–1050 A.D.	McGregor (13)
	Walnut Canyon, Arizona	Pueblo III	1050–1300 A.D.	Carter (13)
	Mesa Verde Step House, Colorado	Pueblo III	1050–1300 A.D.	Carter (13)
	Pueblo Bonito, New Mexico	Pueblo III	1050–1130 A.D.	Judd (28)
C. moschata	Ackmen, Colorado	Basket Maker III to Pueblo I	750 A.D.	Martin (28)
	White Dog Cave, Arizona	Basket Maker II	312 A.D.	Kidder & Guernsey (28)
	Painted Cave, Arizona	Pueblo III	1200–1300 A.D.	Whitaker (32)
	Uaxactun, Dept. of Petén, Guatemala	....	900 A.D.	Vestal (55)
		SOUTH AMERICA		
C. moschata	Ancon, Peru	Middle periods	900–1200 A.D.	Wittmack (46)
	Chincha, Peru	Inca	1430–1530 A.D.	Carter (14)
	Huaca Prieta	....	2000 B.C.	Whitaker & Bird (61)
C. maxima	San Nicolas, Peru	Supe Middle Period	1200 A.D.	Carter (14)
C. ficifolia	Huaca Prieta, Peru	Pre-ceramic, pre-maize	2000 B.C.	Whitaker & Bird (61)

[4] Compiled with the help of Mr. Harold S. Gladwin, Santa Barabara, California, and Dr. George F. Carter, The Johns Hopkins University, Baltimore, Maryland.

relatively little water. They are intolerant of wet, poorly drained soil.

Breeding, Genetics, Cytogenetics

It is beyond the scope of this report to review the surprisingly extensive genetic and breeding work that has been done with the cultivated species of *Cucurbita*. Whitaker (56, 57) and Whitaker and Jagger (63) have reviewed much of this literature. It seems appropriate to include a discussion of the characteristics of the cucurbits that render them attractive or difficult as genetic research material, and the general trends in genetic research.

The plants are easily grown, require a minimum of care, and their individual organs are large. The large staminate and pistillate flowers on monoecious plants serve admirably to instruct inexperienced laborers in the techniques of controlled self- and cross-pollination. The plants are indeterminate so that flowers are available for study and breeding work over a considerable period. Likewise the fruits are large and durable and can be retained for study over relatively long periods of time.

The large size of the plants and of their organs and cells is not entirely advantageous. Except for the short-stemmed bush forms, they require a great deal of space for normal growth. The fruits are large and heavy, so that considerable effort and space are required for their storage. The plants are entomophilous and naturally cross-pollinated to a considerable degree. It is therefore necessary to hand-pollinate flowers on all plants from which seeds are desired in order to make satisfactory progress with either genetic studies or practical breeding work. If, as frequently occurs, field pollinations must be made prior to selection, then it is necessary to hand-pollinate flowers on a large number of plants, or resort to rooted cuttings of selections transferred to the greenhouse and pollinated later.

The *Cucurbita* species are not amenable to cytogenetic analysis (1). The pollen mother cells are large, but the chromosomes are very small and numerous. Preparations suitable for critical study are difficult to obtain by either the

FIG. 10. A fruit of *Cucurbita maxima* var. *Banana*.

FIG. 11. Peduncles in three collections of *Cucurbita maxima: a* and *c,* from South America; *b,* var. Banana (type lacking corky thickening not shown).

paraffin method or the various smear techniques. Most investigations have been confined to counts of the chromosomes. The great diversity of the counts reported (12 to 24 pairs) (7, 35, 47, 56, 59) illustrates the difficult nature of such studies. At present we are limited to the statement that the cultivated species of

FIG. 12. Seeds in six collections of *Cucurbita maxima: a,* var. Gregory; *b,* from South America; *c,* from South Africa; *d,* from South America; *e,* var. Golden Hubbard; *f,* var. Banana. All × 1.5.

(Lettering of seeds in pairs begins with top row and runs from left to right)

Cucurbita, as well as their wild relatives, have about 20 pairs of chromosomes.

Mitosis and meiosis in *Cucurbita* exhibit some exceptional features of interest to the cytogeneticist. The chromosomes do not stain well with aceto-carmine or similar stains in either fresh or fixed material; the cytoplasm often retains the nuclear stains so that differentiation is poor; and relatively large chromatic bodies are associated with the chromosomes during cell division. These

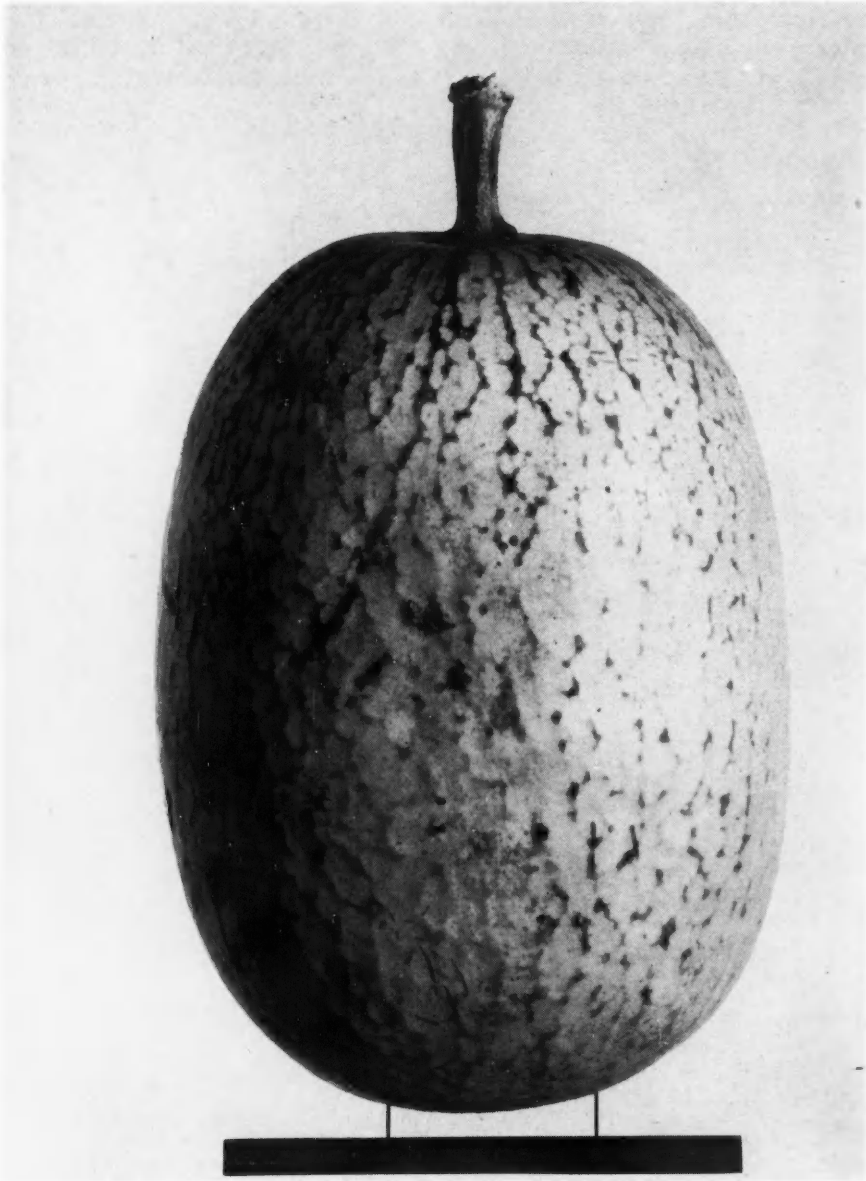

Fig. 13. A fruit of *Cucurbita ficifolia* from Mexico.

bodies have been termed "micronucleoli" (27). Apparently the cell chemistry of *Cucurbita* differs from that of those plants in which the acetocarmine method has been used successfully. Whitaker (unpublished data) obtained better differentiation in acetocarmine smears following the use of iron-acetate acetocarmine as a mordant.

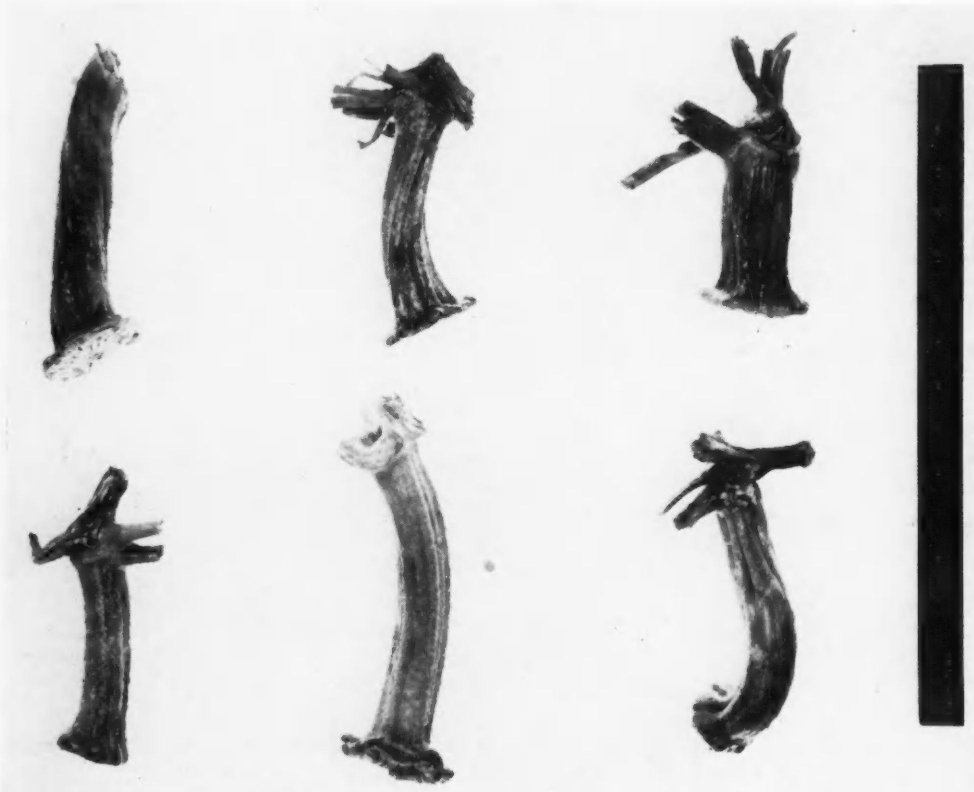

FIG. 14. Peduncles in six collections of *Cucurbita ficifolia: a* and *b,* from South America; *c, d* and *e,* from Mexico; *f,* var. Angurien. All × 1.5.
(Lettering begins with top row and runs from left to right)

Intraspecific Crossing. The cultivated species of *Cucurbita* present a multitude of fascinating characters to the geneticist and plant breeder. Because of the difficulties mentioned, and since most of the breeding work has been done by workers interested in other matters, little precise information is available concerning the genetic mechanisms governing these characters. Major factor pairs are known that affect the expression of a few contrasting characters. Fruit colors and shapes in bush forms of *C. Pepo* have long been used in genetics courses to illustrate dihybrid segregations with independent assortment (49). This type of genetic work has not been extensive enough to permit the formulation of linkage groups.

Many of the characters in this group of plants seem to be affected by a number of minor genes, and this is particularly true of the economic characters that interest the practical breeder. It seems worth noting that those characters

that differentiate the species, as well as those that vary within the species, are quantitative and differ by almost imperceptible degrees among various collections (62). These observations and the similarity of the chromosomes among these species suggest that evolution at the specific and subspecific levels in this group of plants results largely from the accumulation of many minor gene changes.

As stated earlier, the *Cucurbita* species are entomophilous and apparently cross-pollinations often occur. It might logically be expected, therefore, that these plants would lose vigor following inbreeding and exhibit marked heterosis when crossed. However, Smith (51), Bushnell (12), Cummings and Jenkins (22), and Haber (30) found that inbreeding these plants causes little loss of vigor. Passmore (44) and Curtis (23, 24) have published convincing evidence of heterosis in *C. Pepo;* and Hutchins and Croston (33) have reported that F_1 hybrids from crosses between varieties of *C. maxima* produced greater yields than the parents if the larger seeded variety was used as the maternal parent. Shifriss (48) has suggested a hypothesis of developmental heterosis based on a study of the expression of fruit color and plant stature in plants at young and mature stages of development. The degree of heterosis that has been reported in *Cucurbita* is not so marked as it is in maize and certain other crop plants. It is possible that the evolutionary processes that have

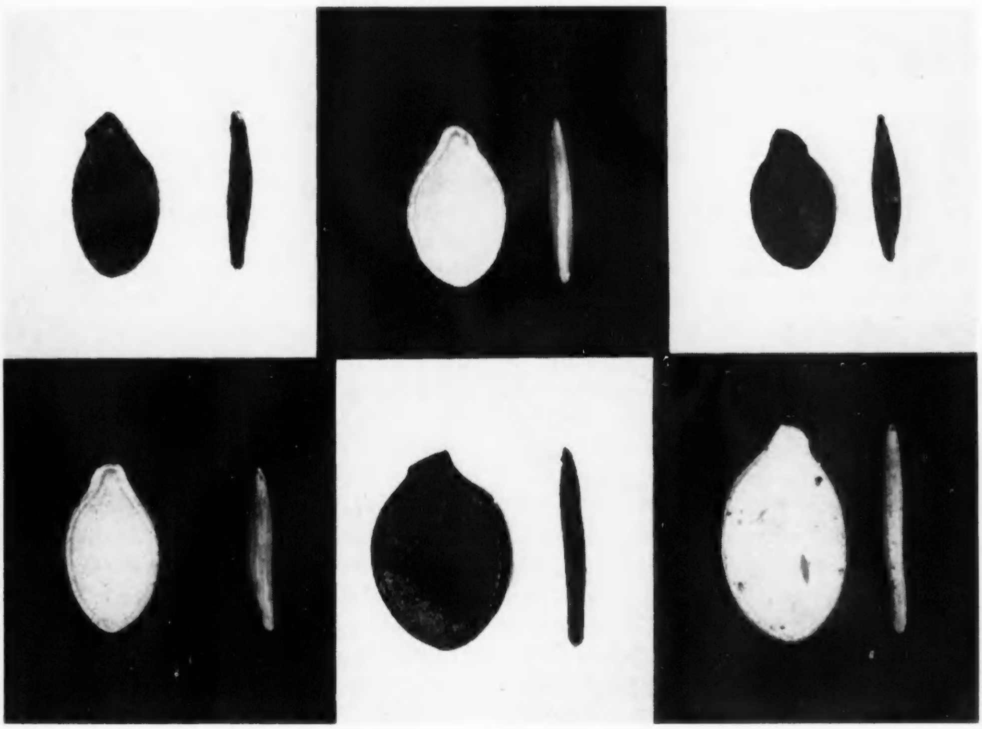

FIG. 15. Seeds in six collections of *Cucurbita ficifolia: a,* A. T. Erwin's collection; *b,* from Mexico; *c,* from South America; *d, e* and *f,* from Mexico. All × 1.5.
(Lettering of seeds in pairs begins with top row and runs from left to right)

resulted in marked heterosis in the classical cases have not occurred in *Cucurbita* and that heterosis in these different groups is not genetically identical. In this connection Crow (20) has suggested that increased vigor in hybrids between natural populations and recovery of vigor following the crossing of artificially inbred strains may be largely due to different genetic phenomena.

Interspecific Crossing. A large proportion of the genetic and breeding work with *Cucurbita* has been and continues to be concerned with interspecific crosses. The enigmatic cross-incompatibilities of plants with similar structure, and the desire to convince laymen that " squashes " and " pumpkins " do not cross or exhibit metaxenia in mixed field plantings, stimulated much of this work. The issue is confused, of course, by the fact that summer squashes and many pumpkins belong in the same species, *C. Pepo*, and are fully cross-fertile. The inclusion of *C. moschata* and *C. mixta* in a single species has also caused confusion.

For the grower or gardener it may be said that there is no measurable immediate effect of pollen from various sources on the quality or flavor of the fruit. So long as seed is from a dependable source, each variety will produce fruits typical of that variety under the prevailing cultural and climatic conditions, whether the variety is grown in an isolated block or in close proximity to varieties of pumpkin, squash, gourd, watermelon, muskmelon or cucumber.

For the seedsman it may be said that one variety each of *Cucurbita maxima*, *C. Pepo* and *C. ficifolia* can be included in a single planting for seed production without fear of contaminating the seed stocks, provided that each species is harvested separately. If it is desired, one variety each of muskmelon, cucumber, watermelon and *Lagenaria* gourd can be included in such an isolated seed increase plot. It is possible that greater seed yields will be obtained if each variety is grown in an individual isolation block because pollen of one species is capable of causing seedless fruits to set from pistillate flowers of another species. *Cucurbita moschata*, which is partly cross-fertile with both *C. Pepo* and *C. maxima*, should be isolated from these two species in seed production plantings. *Cucurbita mixta* should also be isolated from *C. Pepo* until its cross-compatibility with that species is better known.

For the breeder it can be said that crosses can be obtained, with varying degrees of difficulty, between most of the cultivated species of *Cucurbita*, provided that conditions (including methods) are optimum for the production of fruits and seeds, and that contaminating pollen is excluded from the treated flowers. It is necessary to exclude contaminating pollen after as well as preceding pollination. Contamination by self pollen will result in mostly or all self seed, preventing cross-fertilization even if the pistils are cross-pollinated. In this connection Sisa (50) found that pollen tubes of *C. maxima* grow more slowly in styles of *C. Pepo* than do pollen tubes of the latter. In making species crosses it is best to limit the number of treated flowers on a single plant and to remove all non-treated pistillate buds. The young fruits from such cross-pollinated flowers do not compete successfully with those from self- or open-pollinated flowers.

The earlier work on species crosses in *Cucurbita* has been reviewed by Van Eseltine (54) and by Castetter (16, 17), who, with Erwin and Haber (29), performed an extended series of breeding experiments with the commonly cultivated species, including *C. mixta* (designated as *C. moschata* variety Striped Cushaw). The conclusions of those investigators have been confirmed and extended by experiments of the present authors using several horticultural varie-

ties of each species (**58**, unpublished data). Pangalo (**43**) reported *C. mixta* to be cross-sterile with *C. Pepo, C. moschata* and *C. maxima*. Bohn (unpublished data), using the varieties Tennessee Sweet Potato and Striped Cushaw of *C. mixta* and several varieties of each of the other species, found such crosses to be highly infertile; but like Castetter he succeeded in obtaining some viable seeds. Li's (**35**) data and figures suggest that he was working with hybrids from the cross *C. maxima* × *C. moschata* rather than *C. maxima* × *C. Pepo*. The data he reported agree with those obtained from the former cross by Castetter (**16**), Erwin and Haber (**29**) and Bohn (unpublished data). There is considerable evidence that different varieties of the several species differ in their combining ability in species crosses. More detailed accounts of these crosses will appear elsewhere; the present discussion is limited to the general compatibility relationships.

Fruits from attempted crosses between *C. ficifolia* and the annual species frequently contain a few seeds with small embryos. Possibly the embryos could be excised and cultured by special methods. A few viable seeds have been obtained from the cross *C. ficifolia* × *C. Pepo*. Perhaps repeated trials with the other annual species will produce similar results.

Cucurbita Pepo can be crossed with *C. mixta* if the breeder is persistent. The cross-pollinated flowers usually slough but occasionally set fruits containing some plump seeds. Breeding work with this species cross has not progressed to the later generations.

Cucurbita Pepo and *C. moschata* can be crossed in reciprocal matings. The cross-pollinated flowers usually slough but occasionally set fruits with no or very few plump seeds. However, the plump seeds that are obtained produce F_1 hybrids that are self-fertile.

Cucurbita Pepo can be crossed with *C. maxima* in reciprocal matings. Most of the cross-pollinated flowers slough. The few fruits that are set usually contain no seeds or a few seeds with minute embryos. An occasional fruit contains one or two plump seeds. The F_1 hybrids produce staminate flowers with well-developed androecia but little or no viable pollen. They are apparently self-sterile but can be backcrossed to the parent species with difficulty. Amphidiploids obtained from colchicine-treated F_1 seedlings produce staminate flowers with large well-developed androecia and high percentages of normal appearing large pollen. However, they usually fail to set fruits or set seedless fruits from self-pollinated flowers. A few plump seeds obtained in such fruits have produced only self-sterile seedlings. Attempts to establish amphidiploid lines have been unsuccessful.

It is of interest that several viable seeds occurred in a fruit that was set from a flower of the diploid F_1 hybrid treated with pollen from an autotetraploid *C. maxima*. The resulting progeny were vigorous, resembling *C. maxima* in plant and fruit characters. However, they were apparently self-sterile and cross-sterile in reciprocal matings with diploid and tetraploid *C. maxima*.

Dissimilar results are obtained from reciprocal matings between *C. mixta* and *C. moschata*. *Cucurbita moschata* flowers pollinated with pollen from *C. mixta* slough or set fruits with seeds containing no or very small embryos. *Cucurbita mixta* flowers treated with pollen from *C. moschata* slough or set fruits containing similar abortive seeds and a few plump seeds. Apparently these two species are as closely related to the other annual cultivated species as they are to one another.

Cucurbita mixta can be crossed with *C. maxima* in reciprocal matings. Such cross-pollinated flowers usually slough

but occasionally set seedless fruits or fruits containing a few plump seeds and seeds containing small poorly developed embryos. The F_1 hybrids produce staminate flowers that may cease to develop at various stages of growth or continue apparently normal growth. The androecia of otherwise normal flowers may be brown and shrunken at anthesis, or they may be nearly normal in size and color. Androecia that dehisce shed abortive pollen. The few grains that stain with dyes (usually about one percent) vary greatly in size, and most of them are probably non-functional. The F_1 hybrids are self-sterile and cross-sterile, or nearly so, with the parental species. The few fruits that are set are usually without seeds but occasionally contain abortive seeds lacking embryos. Very rarely a few seeds containing small or minute embryos occur in fruits set from flowers treated with pollen from either of the parental species.

Amphidiploids, obtained from colchicine-treated F_1 hybrid seedlings, produce staminate flowers with large, thick, well-developed androecia that shed abundant masses of uniformly large, normal appearing pollen. Fruits from self-pollinated flowers are seedless or contain a few seeds with plump or poorly developed embryos. Amphidiploid lines are established with difficulty and exhibit marked segregation of plant and fruit characters. The amphidiploids are cross-sterile with the diploid F_1 hybrids and the parental species.

The F_1 hybrids and amphidiploids from this cross have plant and fruit characters approaching those of *Cucurbita mixta* and *C. Pepo* and bearing little resemblance to the *C. maxima* parent. The peduncles are slightly or not at all thickened, five-angled, ridged and hard. The fruit flesh is coarse, resembling that of *C. Pepo* in structure and odor. The placenta is dry and stringy, not adhering to the seeds. The seeds, except for their larger size, resemble those of the *C. mixta* parent.

Cucurbita moschata can be crossed readily with *C. maxima* in reciprocal matings. The fruits frequently contain several plump seeds and many seeds with poorly developed embryos. The plump seeds and many of the poor seeds produce viable seedlings. The F_1 hybrids are vigorous and produce average numbers of normal appearing pistillate flowers. Staminate flowers are produced less abundantly than in the parental species. These may develop normally or cease development at various stages of growth. The androecia of otherwise normal flowers may be brown and shrunken at anthesis or nearly normal in size and color. Androecia that dehisce shed abortive pollen. From one to ten percent of the grains may be plump and stain with various dyes, but such grains vary greatly in size and probably most of them are non-functional. The F_1 hybrids are self-sterile but occasionally set fruits with no seeds or a very few poorly developed ones from self-pollinated flowers. They set fruits with a few plump seeds from flowers treated with pollen from the parental species. Seedlings from such backcrosses approach the backcross parent in appearance but have some characters resembling those of the other parental species.

Amphidiploids obtained from colchicine-treated F_1 seedlings are vigorous and exhibit slight " gigas " characters. They are distinguished from the diploid hybrids with some difficulty until flowering. The amphidiploids are then readily identified by their broad-based staminate flowers with large thick androecia that shed abundant masses of plump pollen. The amphidiploids are self-fertile, setting fruits with moderate numbers of large plump seeds. They are cross-sterile with the diploid parental species and constitute a potential new species.

The F_1 hybrids and amphidiploids have many plant and fruit characters intermediate between those of *Cucurbita maxima* and *C. moschata*. The peduncles resemble those of *C. moschata*. They are slightly or not at all thickened, smoothly angled but not ridged, flaring at the attachment to the fruit little or not at all, and hard. The fruit flesh is fine-grained, resembling that of *C. maxima* in structure and odor. The placenta is moderately fleshy, adhering slightly to the seeds. The seeds are large and intermediate between those of the parental species.

The results from interspecific breeding work with the cultivated species of *Cucurbita* are admittedly fragmentary. The cross between *C. moschata* and *C. maxima* has been studied rather extensively, partly because it is less difficult to obtain than are certain other crosses, and partly because it has shown greater promise of producing economically valuable derivatives from diploid backcrosses and from amphidiploids. The cross between *C. moschata* and *C. Pepo* deserves more attention than it has received because the diploid hybrids are self-fertile and continuous inbreeding can be practiced. It seems logical to adopt the working hypothesis that desirable economic characters (*e.g.*, naked seed and resistance to the squash bug, *Anasa tristis* Deg.) can be transferred from *C. Pepo* to *C. maxima* by using *C. moschata* as a bridge.

Studies on the interspecific relationships in *Cucurbita* have produced some evidence regarding evolution in this group. Carter (13) postulates centers of domestication of the cultivated species in a more or less linear order in the western hemisphere: *Cucurbita maxima* in central South America, *C. moschata* (= *C. moschata* var. *Colombiana* Zhit.) in northern South America, *C. mixta* (= *C. moschata* var. *mexicana* Zhit.) in Central America and Mexico, and *C. Pepo* in northern Mexico and the United States. The cross-sterility between *C. mixta* and *C. moschata* supports the hypothesis that these two species have distinct centers of domestication. The separation of these two cultigens into distinct species may materially aid in the evaluation of evidence from various sources on the histories of these plants in cultivation.

If the species of *Cucurbita* spread northward and southward from a center of origin in tropical America, then it can be postulated that *C. moschata* and *C. mixta*, nearer the center of origin, are more primitive than are *C. Pepo* and *C. maxima*. It can be postulated also that *C. moschata* and *C. maxima* were domesticated from common ancestors that migrated southward, while *C. mixta* and *C. Pepo* were domesticated from ancestors that migrated northward. Comparisons of certain characters, such as texture and color of the fruit flesh and structure of the peduncles, support this hypothesis. This comparison is even more clearly evident in the F_1 hybrids obtained from crosses between the species. The hybrids obtained from the cross *C. Pepo* × *C. maxima* and *C. mixta* × *C. maxima* resemble one another and contrast with those obtained from the cross *C. moschata* × *C. maxima*.

The hypothesis is strengthened also by the breeding behavior of *Cucurbita Pepo* and *C. mixta* in crosses with *C. maxima* as contrasted with the behavior of *C. moschata* in crosses with *C. maxima*. *Cucurbita maxima* crosses readily with *C. moschata*, producing partially fertile F_1 hybrids, and self-fertile stable amphidiploids. It crosses with *C. mixta* with difficulty, producing nearly sterile F_1 hybrids and relatively infertile and unstable amphidiploids. It crosses with *C. Pepo* with difficulty, producing nearly sterile F_1 hybrids and amphidiploids that are self-sterile or nearly so. Further breeding and cytogenetic work with these

species and their diploid and amphidiploid hybrids should prove valuable in establishing the phylogenetic affinities among these species. It is important that several dissimilar varieties or collections of each species, such as those postulated by Carter (13) and Whitaker and Carter (62), be used in such work because different varieties of a species do not yield identical results.

Summary

The cultivated forms of *Cucurbita* are of considerable interest because of their long association with man, their value in modern agriculture and their suitability for study in various scientific investigations.

To avoid confusion it is suggested that usage of the terms "squash" and "pumpkin" be restricted to their culinary meanings and not associated with particular species.

The various forms of *Cucurbita* fruits are utilized as fresh vegetables, processed vegetables and stock feed; they also have limited uses as ornamentals. The flesh is sometimes candied or fermented for a beverage. The seeds are used as nut substitutes; they may also serve as sources of vegetable oils.

Based on production costs, winter squashes and pumpkins are high in food value, but summer squashes are low.

Studies on quality and composition under storage conditions have provided a sound basis for handling and processing winter squashes and pumpkins.

Since members of the *Cucurbita* group are considered to be minor crops, production statistics on them are meagre. Their almost universal use in home gardens and their ubiquitous appearance in markets, as well as their extensive use for canning and for stock feed, indicate that the entire group is very important in our agricultural economy.

The cultivated forms of *Cucurbita* are grouped under five species: *C. ficifolia, C. Pepo, C. mixta, C. moschata* and *C. maxima.* The species are identified by gross morphological characters, especially the nature of epidermal hairs and the structure of the peduncle, fruit flesh, placenta and seed.

Archeological and historical evidence indicates that the five cultivated species of *Cucurbita* are of American origin. Their long history as domesticated plants indicates that they have been of major significance in the development of agriculture in the New World. From the probable center of origin for the group in tropical America, *Cucurbita* has apparently migrated northward, producing *C. mixta* and *C. Pepo;* and southward, producing *C. moschata* and *C. maxima.* The perennial species, *C. ficifolia,* occurs near the probable center of origin.

Although tropical in origin, the modern annual *Cucurbita* species are adapted (in association with man) to a wide range of environmental conditions, and their culture has spread to nearly all parts of the world during the past four centuries. *Cucurbita ficifolia,* the only perennial cultigen in this genus, long cultivated at high elevations near the equator, is tolerant of cool temperatures but requires short days for flowering. The annual species seem to be insensitive to day length but require relatively warm temperatures. *Cucurbita maxima* and *C. Pepo,* which have long been cultivated in temperate regions, are more tolerant of cool temperatures than are the tropical and subtropical species *C. mixta* and *C. moschata.*

The chromosomes in *Cucurbita* are small and numerous (about 20 pairs). The failure of ordinary smear techniques to produce satisfactory preparations for cytogenetic analysis suggests that *Cucurbita* may have a unique cell chemistry.

The modes of inheritance of several individual characters are known in *C. Pepo* and *C. maxima,* but no linkage groups have been established. Marked

loss of vigor on inbreeding apparently does not occur in these species, but moderate degrees of heterosis have been demonstrated. These facts suggest that the genetic basis for heterosis in *Cucurbita* may differ from that in maize and some other plants.

The attempt has been made to harmonize the extensive reports on hybridizing with the authors' studies. Certain pairs of species can be crossed with less difficulty than others, and some crosses have not yet been successful. Different horticultural varieties and collections vary in their combining ability in species crosses. It may logically be expected that those combinations of species not yet successfully crossed will eventually yield hybrids following repeated trials with different collections and varieties, or by the use of special techniques.

The cross *C. Pepo* × *C. moschata* produces F_1 hybrids that are self-fertile. The F_1 hybrids from the cross *C. Pepo* × *C. mixta* have not been reported. Other combinations of species that have been crossed produce F_1 hybrids that are male-sterile but partly female-fertile in backcrosses to the parental species.

Amphidiploids derived from the cross *Cucurbita maxima* × *C. Pepo* are self-sterile, or nearly so. Those from the cross *C. maxima* × *C. mixta* are slightly self-fertile and exhibit marked segregation. Amphidiploids from the cross *C. maxima* × *C. moschata* are self-fertile and cross-sterile with the parental species. They exhibit some segregation but are relatively stable and constitute a potential new species.

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Utilization Abstract

Panama Hats. In his recently published book, " Ecuador and the Galapagos Islands", Victor Wolfgang von Hagen has provided a very interesting chapter on the Panama hat industry which has been reprinted in the March, 1949, Journal of the New York Botanical Garden. The picturesqueness of the native market where these hats enter world trade and the haggling that is involved in the sale of each item are briefly and effectively described, but defy abstraction without serious detraction. The more prosaic parts of this brief account furnish the following information. The manufacture of Panama hats, so called because Panama was formerly their point of distribution, is genuinely a cottage industry of Ecuador carried on by over 200,000 weavers—children, adults, Indians and cholos—within a radius of 40 miles of Cuenca, 8,500 feet above sea level. Today 85% of all Panama hats come from this region, in the province of Azuay, though the original center of the industry was the province of Manta, particularly the towns Montecristi and Jipijapa (hé-pe-há-pa). These original centers are in the hot and arid littoral where the Panama-hat plant (*Carludovica palmata*) is indigenous. This palm-like plant " is a small stemless species six to fourteen feet high with fan-shaped leaves, four feet in diameter, having the deep indentations in the leaf of the family Cyclanthaceae. The natives call it 'paja toquilla'. Now, with the growth of the panama industry, whole plantations are given over to its culture. To convert it into fiber, the large green palm leaf is cut from the base of the tree, stripped of its outer filaments, thrown into boiling water, then set out to bleach under the equatorial sun. When sufficiently whitened, the straw is cut into small strands, which shrivel dry into cylindrical form. Cordlike in texture, they are over a yard in length ".

In Manta, where the climate is hot and dry, the weavers must frequently moisten the desiccated straw to keep it pliable, and this custom has given rise to the legend that the fine straw hats are woven under water. Whereas the finest hats, earning for the weaver $10 to $30 each but eventually retailing for $100, are still made in Manta, the bulk of the trade comes from Cuenca.

After being woven the hats are bleached with sulphur fumes emitted from small braziers, and for this purpose 1,000 tons of sulphur are gathered yearly from the volcanoes of Ecuador. A bath in the milk of sulphur follows, and subsequent blocking, pounding, pressing and cleaning render the hats ready for market. In Cuenca, where every Thursday is marked as the day of the Panama Hat Fair, as many as 30,000 hats may be sold to a variety of buyers, including agents of the Ecuadorian Panama Hat Company buying for fashionable shops in New York and elsewhere.

Utilization Abstracts

Opium. In October, 1949, the Department of Social Affairs of the United Nations published No. 1 of a new quarterly known as "Bulletin on Narcotics" which will "attempt to give the most recent news on the results obtained in the control of narcotic drugs and the struggle against addiction, by Governments, by the United Nations and by the organizations established under the Conventions. It will contain technical and scientific articles on narcotic drugs and articles on the legislation and administration in various countries as well as bibliographical material".

This first bulletin contains two articles on opium, one on its production throughout the world, the other on the physical and chemical tests that aid narcotics authorities in identifying opium seizures and thus finding the sources of illicit traffic. Production, trade and use of the drug in 30 countries of the world are discussed under as many headings.

The more general information in this bulletin may be excerpted as follows:

"The opium poppy can be grown in most of the habitable parts of the world except the northernmost, up to at least latitude 56°. Where this poppy can be grown, opium can be produced, though not always profitably or legally. In a number of countries the opium poppy is grown for its seeds, and not for opium at all. It is then referred to as 'the garden poppy', instead of 'the opium poppy', but it is just the same plant, scientifically known as *Papaver somniferum* Linnaeus. The seeds are a valuable oil-containing food, and are also pressed for the oil, which may be used as a table oil and for other purposes, such as artists' paints. The pressed-out poppyseed-cake is used as feed for cattle".

"There are many species of poppies, but only *P. somniferum* is known to elaborate morphine, and therefore it is the only poppy known to produce a true opium. It is also the only poppy grown commercially for edible seeds. Sometimes, like other poppies, it is grown merely for its flowers. It has numerous floral varieties, single and double, with petals spotted at the base with either violet or white, and colors ranging from pure white through pink, lavender and red, to very dark violet. The familiar Shirley poppies, and their progenitor the common red poppy (*P. rhoeas*), and the showy Oriental poppies (*P. orientale* and *P. bracteatum*) produce no morphine and should not be mistaken for opium poppies. In this article, when there is reference simply to the poppy or poppies, *Papaver somniferum* is meant".

"*Papaver somniferum* is grown primarily for its seeds, both commercially and in the home vegetable gardens, in a great belt across central Europe, taking in the Netherlands, Belgium, northern France, southern Germany, Switzerland, Austria, Hungary, northern Yugoslavia, Czechoslovakia, Poland, Romania and the Ukraine. The southern European countries very seldom grow the poppy for its seeds because as an oil producer it cannot compete with the olive. In the great poppy belt of Europe there is almost never any production of opium, but since the 1930's, a number of these countries have begun to utilize, to some extent, the dried poppy plant material or capsule chaff left over from threshing out the seeds, for the direct extraction of morphine and the manufacture of opiates. The United States, Australia, Chile, Argentina and Italy may also be mentioned as having experimented with the utilization of poppy chaff".

"Occasionally, *e.g.*, in France or England, a limited cultivation is primarily for the capsules which are cut green and dried for pharmaceutical use. They are used in official medicine in some countries and in some for home medicines such as sleeping potions or cough syrups".

"But the greatest cultivation of the poppy, chiefly in Asia, is for opium. A few days after the flower petals fall the cultivator scratches the outside of the green capsule with a knife. A white, milky juice flows out. Usually it is left to dry on the capsule for several hours, then collected. It gradually turns brown on exposure to the air and coagulates with standing and drying. This coagulated juice of the poppy is opium".

"The opium poppy is an annual plant.

Mainly, the seed is sown in the fall. It can also be sown in spring, either by choice or to replace a fall sowing which has failed. The harvest takes place between May and August".

"The original home of the opium poppy is probably the Mediterranean region, and probably its cultivation first began near the eastern end of the Mediterranean. The culture for seed seems to have come first, perhaps coupled with a knowledge of the soothing and sleep-producing powers of the capsules, when made into 'poppy tea'. The knowledge of the concentrated drug, opium, is known to be more than 2,000 years old in eastern Mediterranean lands. The culture for seed has moved chiefly northward and westward, and is very ancient in Europe. The culture for opium, and with it the common use of opium as a drug of addiction, reversing most world-trends has spread from west to east. Originally, opium as a drug of addiction was eaten, or drunk as an infusion. The smoking of opium, which became such a terrible vice among the Chinese, is comparatively recent, only some hundreds of years old. Opium culture is believed to have reached Japan about 500 years ago. Only in recent years has it crossed the Pacific and become established to a certain extent, though wholly illicit and under constant attack, in the mountains of western Mexico".

"Here it may be mentioned that opium is often, though by no means always, produced in mountainous regions. Illicit production, of course, is likely to be located in hidden valleys and places of difficult access. But even licit production is more likely to be in out-of-the-way places. Opium is a good cash crop in many lands; it has a fairly high value in proportion to its bulk and weight, and no important difficulties of transport or storage. Where good roads offer easy access to large markets, some more bulky crop may be as profitable to the farmer as opium, even if there are no important governmental restrictions. In mountainous, backward areas, where roads are few or non-existent, opium may be one of the very few crops that can be produced profitably for sale in the outside market".

"Turkey is the chief opium exporting country of the world. There is no domestic manufacture, and there has been no exportation to opium-smoking countries since 1941—the entire production, except for some possible smuggling, is exported to the manufacturing countries. The Ministry of Agriculture fixes each year the areas where opium can be produced. Ordinarily the same twelve vilayets are named in which production is permitted in the whole vilayet, and some counties in other vilayets, which may be changed from year to year. There are three producing districts. . . . There are some additional areas in which the poppy may be cultivated for seed alone. No production of opium is permitted within about 100 kilometres of the border or coast. Turkey tries to maintain a constant production of opium. The area is intended to be about 30,000 hectares or a little less each year. . . . The average production has been some 243 tons annually (1938-1947) and the average exports nearly 201 tons. The difference is largely due to drying . . . trade in opium is free in Turkey. That is, any one may possess opium".

Sisal. After eight years investigation a British report on byproducts obtainable from sisal (*Agave sisalana*), which is extensively cultivated in Tanganyika for its rope-making fiber, states:

"In years to come the fibre and tow which have heretofore been the only saleable products of the estates may become of much less importance in the economics of the sisal industry, possibly sinking to the status of a byproduct of secondary importance to the higher priced new products extracted from the fleshy non-fibrous material which constitutes an equal proportion of the leaves to that represented by the fibre".

These potential byproducts obtainable from sisal waste and regarded as eventually capable of surpassing the fibre in value are:

a) Cold water extracts of malic, succinic and citric acids, glucosides, fermentable sugars and saponins. One such extract has been found to have excellent anti-corrosive properties, and another to prevent scale formation in boilers. "The fermentable sugars could be used for the production of power and industrial alcohol and other fermentation products".

b) Chemical extracts containing pectins and pectates. This group "represents about 15 per cent of the waste and is of most immediate importance since it is already being

produced on a commercial scale and a number of derived products are now being marketed. They are in active demand and future requirements of the market may soon prove large enough to absorb all that can be extracted from the waste obtainable from existing plantations".

"Pectins represent only a small proportion of the chemical extract . . . Pectates (sodium, calcium and other metallic salts of the acid) are being produced for a number of industrial and agricultural uses".

c) Solvent extracts—wax, chlorophyll, xanthophyll, carotene. Of these, wax is the most important, amounting to about 5% of the waste and resembling carnauba wax [the most important of vegetable waxes, obtained from the leaves of the wax palm, *Copernicia cerifera,* of Brazil].

d) Residual materials—50% of the waste. Useable as sources of acetic and butyric acids, sugars, lignin, plastics and wallboards. (*Chemical Age 60: 7. 1949*).

Straw Paper-Pulp. "Straw pulp has been used for the manufacture of paper and board since about 1800. Straw paper was widely used for wrapping meats in the United States until the early part of this century, and is still used for this purpose in some parts of Europe. Newsprint and many types of fine paper at that time also contained straw pulp blended with rag and other paper-making pulps. Even after the introduction of wood pulp, straw continued as a part of the furnish for many fine as well as coarse papers produced in this country.

"In both Europe and South America bleached straw pulp is still an important ingredient of many types of fine papers and boards, including writing, book, magazine, bond, and bristol and art papers and boards. The straw pulp is generally blended with wood and rag pulps and the desired characteristics of the products are obtained by judicious proportioning of the various types of fibers".

"The main commercial use for straw in the paper and board industry in the United States today is in the manufacture of corrugating strawboard. Wood pulp has replaced straw pulp in practically all other types of paper and board, and is also being used for corrugating. The higher density of wood, the relatively low cost of groundwood (mechanical) pulp, the long fibers of coniferous wood pulp and the relative ease of wood collection have been among the more important factors favoring the use of wood over straw".

"Straw pulp and paper are manufactured and used in Europe and South America, particularly in those countries which lack pulpwoods. A number of mills in Holland, France, Germany and Italy produce excellent bleached papers and boards with wheat and rye straw pulps as major constituents of these products. . . . The English turned to straw during the war, and produced good grades of many types of paper from straw pulps prepared in their esparto (*Stipa tenacissima*) and wood-pulp mills. At present Great Britain is in the process of establishing a permanent straw pulp industry. Argentina has one of the largest straw-pulp and paper mills in the world, with a daily production of about 100 tons of bleached pulp from wheat straw. Paper and board products from wheat and rice straws are also produced in Brazil and in other South and Central American countries. Beautiful, bright, strong bleached papers are made from rice straw in Java. Many other countries use straw pulps for the production of fine specialty papers and boards".

Investigations are now under way at the Northern Regional Research Laboratory, Peoria, Ill., toward improving the pulping processes whereby there may be greater utilization of surplus cereal grain straw on American farms, enormous quantities of which are burned every year. In this work straw pulp is not regarded as a substitute for paper pulp, but as a supplement to it, for "it is believed that every plant fiber, or at least every class of plant fiber, has some characteristic property or properties peculiar to it. . . . Well-known commercial enterprises based on the specific properties of the raw materials involved are the production of superior insulating board from the sugarcane bagasse, of corrugating paper from wheat straw, of cigarette paper from seed flax straw, and of thin book and Bible paper from esparto". Straw pulp may be used pure or in mixture with other pulp, according to the characteristics desired in the final product. (S. I. Aronovsky, *Chemurgic Digest 8(7): 4. 1949*).

A BOOK IN BRIEF

Flight from Reality[1]

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Since time immemorial, man, in every stratum of his society and in every segment of his competence, has sought "some brief respite from the disenchantments of reality", for "who is ever really free from care, gloom, apprehension, boredom, or mental fatigue—free enough to float the mind above the sordid anchorage of reality"? Thus writes the author in the introduction to this highly informative and entertainingly written book on those products of the plant world which for ages have narcotized those who have sought "flight from reality". The desire for these elixirs is so innate in man that to attempt legislative prohibition of them, rather than control of their abuse, is absurd, in the opinion of the author, for "next to the instinct of survival it has dominated more people than any religion, costs more than any food, and it yields in this country more than two billion dollars' yearly revenue to the United States Treasury".

Elsewhere in this volume the author states: "Even a superficial glance at the literature of anthropology, botany, pharmacology, and narcotics should convince the curious that they deal not with depravity but with a human need beyond the strictures of the moralist, buried deep in the very fiber of man's existence. How else explain the discovery of cohobo (*Piptadenia peregrina*) by the ancient Caribs of Haiti, a narcotic which is known today under a variety of names in Amazonia, and still used in Colombia under the name of 'niopo snuff'? It has nothing to do with tobacco although it is used like snuff. Henbane (*Hyoscyamus niger*) and the related genus *Datura*, both containing deadly alkaloids, were used for centuries in all-but-unprintable rites, ages before their legitimate use in medicine. Even today a derivative of *Datura Stramonium*, the common Jimson weed, is used criminally in a mixture of sexual excitants to break down the will of girls attempting to resist prostitution. Properly extracted, the plants of this family yield such valuable medicines as stramonium, scopolamine, atropine, hyoscyamine, and other alkaloids. Less well known, but used long before coffee was heard of, is the African khat (*Catha edulis*), the constant use of which so reduces libido that marriages among its addicts are few or late".

"Also from Africa, mostly near Gold Coast and in the Congo valley, the natives discovered the kola nut (*Cola acuminata*), rich in caffeine. It became notorious not only for its caffeine content, but because the women slave carriers upon whom the traffic depended were once subjected to barbaric cruelties. Why, too, should the women of India have turned to the root of kaner (*Nerium indicaum*), a sweet-scented relative of the equally poisonous oleander. Kaner, in less than dangerous doses, has been so much used by rejected or jealous women of India that their more fortunate sisters taunt them by saying, "Go and eat of the kaner root". Many suicides are on record from eating too much, for the plant yields a dangerous alkaloid. How, one asks, could frustrated women of India, centuries ago, have discovered the peculiar narcotic effects of these roots? And how or why did the ancients discover the virtues of darnel (*Lolium tremulentum*), a grass without narcotic properties until, like ergot, it is attacked by a fungous disease? Greeks and Romans knew it well, and used it sometimes in such large doses that narcotic visions were followed by death".

"By far the most famous of these secondary agents of escape is the mandrake (*Mandragora officinarum*), not to be confused with the American mandrake or May-apple. The true mandrake of Eurasia is a perennial herb, the root of which is often bifurcated, manlike, and has been the subject of countless legends, some of them blasphemous and nearly all unprintable. For a thousand years credulous oriental women bought the roots upon the wholly gratuitous assumption that they would promote conception. Its more

[1] 237 pages. Duell, Sloan and Pearce, New York. 1949.

legitimate use by the ancients was as a powerful and pleasant narcotic. They knew so much about it that, before operations, they gradually increased the dose, thus producing a kind of anesthesia centuries before ether was discovered ".

" All of these plants, and hundreds of others, have been rescued from the wild by people as far apart ethnically as Siberian peasants and Melanesian islanders, and geographically so separated as to include the Arctic tundra and Amazonian rain forests. Not a country in the world is without such plants. It is significant that peoples feeling the need for them should have discovered their concealed and magical properties without benefit of modern techniques ".

The history and legends associated with these and other alkaloid-containing plants are discussed by Mr. Taylor, as well as the moral and social aspects of their use. The botanical and other pertinent aspects of the most important are as follows:

MARIHUANA

Indian hemp (*Cannabis sativa*) is the well-known source of hemp fiber used in cordage and described as such in ECONOMIC BOTANY, **2:** 158–169, 1949, but other products derived from it have for centuries given it importance, especially in China and India, as one of the means of achieving " flight from reality ". This quality rests on the fact that the tops and flower clusters of pistillate plants, hemp being dioecious, produce a resinous exudation which, when imbibed in various forms, induces effects ranging from mild stimulation to insanity, according to the frequency and doses as well as other factors. There is a voluminous literature on the subject, describing the hallucinations and other experiences induced by this drug, and today nearly every American State has laws against possession of the plants or their products, with penalties ranging from heavy fines to ten years in jail (Oregon).

Soporific use of the resin from hemp goes back, first in China, then in India, 3,000 years before Christ, and in India cultivation of the plants for the resin long ago became an art. " In Nepal, where the finest hemp was formerly grown, the plants were set out in long rows, spaced so that mature flowering tops would just touch. Some resin develops even before the tiny greenish flowers are ready to bloom. To prevent its loss would be easy by simply cutting off the tops of such precocious plants. But that would mean losing the resin of the main crop. To overcome this dilemma, and capture all the resin, completely naked men were driven at intervals pell-mell through the hot steaming rows of hemp, and what stuck to them was scraped off. If this seems a little exhausting, under a tropical sun, it was scarcely improved by the fact that the workers were forced to thrash their arms about so that every inch from the waist up would have its clinging coat of resin ". Some time later the naked runners were made to catch the resin on large leather aprons, and today " resin is now coaxed out of the cut flower clusters with all the care that the most finical could demand. Spread between snowy cheesecloth, it is pressed out and then scraped off the cloth ".

The resin obtained in either the primitive or the improved manner has for centuries been known to the Hindus as " charas ", " churus " or " churrus ", and to the rest of the world as " hashish ". From it modern medicine derives the drug known as " Cannabis indica ", used " to relieve pain, especially headache, encourage sleep and to soothe restlessness ", a drug which the pharmacopoeia says must come from the " dried flowering tops of the pistillate (female) plants of *Cannabis sativa* ". In India charas is obtained from a specially cultivated and harvested grade of female plants of Indian hemp, known as " ganja ", and the growing of such plants there is a licensed agricultural industry. The term " ganja " is applied also to the cut and dried tops of these specially cultivated female plants, used in smoking mixtures, beverages and sweet meats without extraction of the resin. Dooryard plants, uncultivated and with less resin content, are also cut by the natives " without extracting the resin, and from the cut tops a decoction in milk or water is brewed. This is the celebrated 'bhang' of India. Since tobacco pipes were brought from the new world, bhang is now often dried and smoked, in which form it is a little more potent than as an infusion. But bhang is about the cheapest method of using hemp, and is still

scorned by all but the very poorest in India. It is, under the name of 'marihuana', practically the only hemp product known in America ".

OPIUM

Opium is the air-dried coagulated milky juice obtained from unripe pods of the opium poppy (*Papaver somniferum*). Collection of it "has scarcely changed since Dioscorides first described it in a book written nineteen hundred years ago, although the narcotic properties of the plant were known at least fourteen centuries before that. A few days after the petals fall, the unripe, greenish pod is carefully slit by a very sharp, several-bladed knife, but not deeply enough to cut into the interior of the capsule. From this cut rind there exudes—especially in hot weather—a milky juice which coagulates in about twenty-four hours. This is then carefully scraped off and, after cleaning, becomes commercial opium, which is gummy and dark-colored ". This harvesting occupies "an army of men, women, and children in Turkey, Asia Minor, Macedonia, Yugoslavia, Bulgaria, Persia, China, and India. Of all these by far the best, and almost the only one sold in the United States, is the opium grown in Turkey. There is also an enormous production of quite inferior opium in China, most of which is used there ".

It is this dried latex that has been used in the Orient for centuries as a soporific, and today well over 900 million people are still apt to use either it or Indian hemp, or both. Its qualities are due to the alkaloids contained in it, over two dozen of which have been isolated. The most important of them are morphine which as a properly administered medicine is the greatest alleviator of pain the world has even known; heroin, "so dangerous that even for medical uses its importation and manufacture in this country are forbidden "; and codeine, "useful in cough remedies, and widely used in sedative prescriptions as it does not generally induce addiction. It has about one-tenth the sedative effect of morphine ". Paragoric, once a favorite medicine for children, is camphorated opium tincture.

Only the capsule juice of the opium poppy is narcotic, no other parts of the plant. The seeds are commonly sprinkled on rolls or buns, and an oil pressed from them (maw oil) is widely used as an adulterant of olive oil.

OLOLIUQUI AND PEYOTL

These two plants, native to Mexico, have been used as intoxicants in that land since before the Conquest, and played an important part in those days in ritual ceremonies and divinations. "Quite apart from their use in Indian magic, these two plants have been and are still used for their effects upon the mind and nervous system of a people long inured to hardship. . . . Trade in both products exists, with the result that each is now known over much of Mexico. But the origin of ololiuqui in and near Oaxaca, and peyotl near the Texas border, seems well established ".

Ololiuqui (*Rivea cormybosa*) is a woody-stemmed vine closely related to the morning glory, growing throughout southern Mexico, with a single lentil-like seed in its small fleshy fruit. "As to the veneration in which the plant was and still is held, there can be no doubt. The seeds have a threefold function—as a narcotic, a medicine, and as part of the ritualistic hocus-pocus of divination. Among all but the most ignorant Indians of southern Mexico the latter virtue of ololiuqui has waned. As a medicine, in spite of the Department of Public Health at the capital, it is certainly still in use. . . . The seeds are in no modern pharmacopoeia, but in many native ones. . . . Its great use, before, during, and even since the Conquest, has been as a narcotic which is supposed to confer peculiar powers. . . . Unlike most others, nothing is known of the chemistry of the alkaloid and glucoside recovered from its seeds. Whatever the active principle, it seems to be most effective, for it ultimately induces a kind of hypnotic sleep or coma ".

Peyotl is a very insignificant-looking cactus (*Lophophora Williamsii*), native to northern Mexico and southern Texas, seven-eighths of which is buried in the ground as a turnip-like single taproot. It "is never very abundant, and may some day be exterminated because its collection has gone on from remote antiquity ".

"The part of the plant which appears above ground has led to not a little confusion, for it looks like a cluster of small,

button-like mushrooms, and many have frequently mistaken it for mushrooms. To further complicate the picture, there actually was a narcotic mushroom in ancient Mexico, recently identified and appropriately christened in appropriate Latin, but its use is minor and it should no longer befog the history of peyotl. It does, however, for the error is very old and at the time of the Conquest peyotl was often called the 'Sacred Mushroom'".

"That error left a legacy which generated some later confusion. In Texas, where the peyotl is also native, the small mushroom-like buttons came to be known as 'mescal buttons', which is singularly inappropriate, for mescal is an alcoholic beverage of Mexico and bears no buttons. In the United States, however, 'mescal buttons' will probably always be the name for peyotl, and 'mescaline' is still the proper term for the chief alkaloid found in these curious dried cacti . . . the only one of the huge cactus family that has so far produced an alkaloid which will mitigate the intolerable impact of life".

"To call them 'buttons' was, to all who never saw them growing, perfectly natural. Only a comparatively few Indians knew that the parsnip-like base of peyotl was topped by a ribbed summit, that unlike most cacti it was spineless, and that among the ribs were button-like growths bearing a small, rose-tinted flower surrounded by a tuft of whitish hairs. These grayish-brown growths, which average a little less than two inches in diameter, look, when dry, very much like a shriveled mushroom. It is in this form that they are sent to the capital, and it is only in the form of these 'mescal buttons' that most of our own Indians ever see peyotl".

The "buttons" are gathered by several tribes in northern Mexico, amid considerable ceremony which varies according to the tribe. Despite a United States law against them, the "buttons" are imported from Mexico and the Rio Grande region of Texas by the Apaches, Omahas, Kiowas, Comanches and other tribes of the American Southwest. The peyotl cult was originally confined to Mexico, but has extended as far as Wisconsin where a few years ago an Indian defendant was acquitted in a trial charging him with use of the material. "The chief defendant was acquitted on the ground that the peyotl cult was 'religious'—as in fact it may have been, considering that the Indians took peyotl as the faithful do communion".

ALCOHOL AND TOBACCO

These two plant products, to which Mr. Taylor devotes more than 50 pages in his book, are so well known as not to merit extensive mention here where the lesser known intoxicants are of more immediate interest. It may be mentioned, however, that production of alcohol is based upon fermentation of sugar by yeasts, and in speculating upon the first primitive people who discovered the process, Mr. Taylor writes: "Millet, barley, and, much later, wheat, were cultivated by these people for food. None of them contain enough sugar for fermentation, but all of them contain starch. The dramatic moment, for the history of the world, hinged on who would be the first to find a way to turn these starches into sugars, and hence allow the yeast plant to begin controlled fermentation. It seems reasonably certain that this was first accomplished by chewing the grain and spitting out the juice, for in this primitive process starches are changed to sugars. Such a method may strike the fastidious as a rather disgusting origin for the first beer ever known. But it has lost none of its efficiency and is still popular in tropical America. The best chicha in Peru and Bolivia is still made from corn chewed by Inca women, who allow the spittle to ferment. This is such a superior sort of native beer that throughout the Andes its makers are, by custom, permitted to put a special mark on their houses. Then, too, the picturesque kava-drinkers of the Pacific Islands had for centuries no other method of inducing fermentation. . . . Once the principle was understood it did not take too long before beer was made from malt, which eliminated the spittle technique". [Kava is produced from the root of *Piper methysticum*, and the principle involved in malting is that the enzyme diastase is produced in germinating barley grain and converts the starch of the grain into sugar.—Ed.]

COCA

Cocaine, the well-known pain killer, is obtained from the leaves of *Erythroxylon*

shrubs, and the world's principle source of the drug is Java where the Dutch have developed high-yielding strains of the shrubs on plantation scale. The plants are native to South America, particularly Bolivia and Peru, but in those countries their content of the alkaloid is not sufficient to make commercial extraction of it profitable. The presence of other alkaloids in the plants, however, have made them of great importance to the natives of those countries, from the Incas to the present-day Indians, and there is now an annual crop of dried leaves of over 50 million pounds, grown and harvested to be used solely as a masticatory known as " coca ".

" The culture of coca for chewing is the major agricultural enterprise of Bolivia, where it covers some thirty thousand acres of a region not fit for much else, except possible cinchona culture. It is grown in 'cocals', usually not over an acre or two, and these miniature farms look like gigantic steps up the incredibly steep mountains chosen for its culture. The terraces are about a foot wide, and in this narrow trench is planted a close hedge-like growth of coca bushes—none over eighteen to twenty-four inches high. Hundreds of women and children, often in gaily colored clothes, pick the small, privet-like leaves, usually twice or three times a year. Coca-picking, which has been going on for over ten centuries, often from the same cocals, has always been something of a festival. It is today big business, but it still retains its colorful Inca heritage. As one creeps along the trail through the valley, the coca terraces, lost in the luminous haze of a misty skyline, seem like the seats of a huge amphitheatre dotted with splashes of color amid threads of bright green ".

Use of these leaves as a masticatory has for ages provided the natives with a remarkably stimulating relief from the pangs of hunger and the fatigue of their strenuous life in a land that offers little by way of comfort. " Here live many millions of Indians, all descendants of the Incas, and, like them, still chewing coca. Stolid, unsmiling, vigorous, supremely healthy, these tough mountain folk have thrived for centuries in an environment that would have eliminated most of us. Without wood or coal for fuel there is the incessant fight against cold, their only substitutes being the reluctant fires from evil-smelling llama dung or clumps of ichu grass—both entailing endless effort. Until the Spaniards came they did not know the wheel, and had no animal they could ride, as the llama resists such efforts by turning its camel-like head and showering its rider with spittle. How, one asks, could such a people, without beef or milk cattle, no sheep or pigs, no tea, coffee, or sugar, no wheat, rice, or bananas, have made their incredibly solid buildings, their great network of stone roads, and an irrigation system second only to that of Holland? They had an answer then and still believe it today ".

That answer lay in the effects obtained by chewing coca, and " the modern Indian, like his Inca ancestor, is equipped with certain essentials for traveling—a bag, often of beautiful vicuña fabric and design, for carrying the dried leaves, a brick or two of alkali (locally called 'llipta'), the small gourd for carrying it (the 'poporo'), and a small spatula-like stick for extracting the llipta. While all of these have been found in Incan burial urns of great antiquity, the modern counterparts, often of great beauty, are found on every mountain road of Peru and Bolivia today.

" The brick of alkali, usually about the size but half the thickness of a match box, duplicates in its action a similar product found in the Far East, where betel-chewers mix that nut with a little birdlime. In South America these bricks can be bought in any market very cheaply, for they are mostly made by sticking together the ashes of quinoa [*Chenopodium Quinoa*] with a little starch made from corn ".

" So equipped, an Indian will walk for days with a heavy pack and very little food. Every hour or so he will add to the ball of chewed leaves (which makes one cheek look as though he was holding a large marble in his mouth), and take a bit of alkali with each fresh chew. This is such an invariable ritual that there is even a name for it, 'cocada'—the period that a chew will last. Its effect in destroying fatigue is astonishing, and derives not only from its food value but from its direct action on the nervous system ".

In 1548 the Spaniards bought over two million pounds of coca leaves to stimulate their Inca slaves in the fabulous silver mines

of Potosi, and before 1904, when its use became illegal in the United States, coca was included in the formula for Coca-Cola.

PITURI

Pituri, known also as "pecherie", "pedgeri", "pitchuri" and by 17 other variants, is a shrub or small tree (*Duboisia Hopwoodi*) confined to the semi-desert regions of Australia. "So poisonous is the plant that some natives who never chew it, throw it in the water holes used by the emu, who quickly becomes stupefied and hence easily caught. They also use it to poison fish, and it is more than likely that its use for this and for stupefying game antedated, or perhaps suggested, its first experimental use by the natives themselves. Its effects are wholly on the nervous system, so that pituri-stupefied emu was perfectly safe to eat, just as is game stopped by curare-tipped arrows. A species related to pituri is now cultivated by Australian scientists as a commercial source of alkaloids deadly in improper doses but yielding valuable medicines to science. Pituri, while not the chief source of scopolamine, is one of the few plants which yield it". [See ECONOMIC BOTANY, **3**: 215, 1949, for pertinent abstract.]

"Scopolamine, like so many of the alkaloids of the potato family, has the extraordinary power of making one forget everything that happens while under its influence. It was this that made it so popular, twenty years ago, as the wonder drug for so-called 'twilight sleep' in childbirth. Australian natives know nothing about scopolamine, and have their babies in more normal fashion, but their addiction to pituri stretches back for centuries before the first Europeans reached Australia.

"The leaves are collected while the plant is in flower, dried, roasted, then moistened, and finally mixed with the ashes from some burned acacia wood. Like the coca-chewers of the Andes and the betel-chewers of Malaya, the Australian natives stumbled on the fact that the addition of an alkali stepped up the effects of pituri. The mixture is rolled into quids about two and one-half inches long and finger thick. This makes a convenient size for chewing, while it also permits the universal custom of carrying the quid, while not in use, behind the ear, much as some of us carry a pencil. After repeated chewing, the lump is finally swallowed".

"The crude products, unlike scopolamine, are violently irritating to the nose, throat, mouth, and eyes, but the natives, who well know its danger in too-large doses, put up with these side effects for the sake of its value in killing fatigue, reducing hunger, and, more important than either in a desert country, its temporary reduction of the need for water".

FLY AGARIC

Fly agaric (*Amanita muscaria*) and the destroying angel (*A. phalloides*) are two deadly mushrooms, the alkaloid in the former being "muscarine, a complicated substance so poisonous that before the advent of sticky fly paper a decoction of it was long used to kill flies—hence the name 'fly agaric'. In the forests and forest-edges of New York State, the fly agaric has a whitish stalk, swollen at the base, a lacerated collar about three-quarters of the way up the stalk, and a gorgeously colored umbrella-like cap (pileus) from three to eight inches wide. In North America the cap will be mostly whitish, yellowish, or orange-red, but in Europe and Asia bright-red or purple. Hence the title of the amusing and fanciful short story by H. G. Wells, 'The Purple Pileus'. In all regions the cap is covered with many whitish, yellowish, or reddish warts".

"For hundreds of years certain tribes of primitive peasants in central and northeast Siberia have used fly agaric, and the most primitive of all, the Koryaks, Kamchadales, and the Chukchee (or Chukchi) have been guilty, especially the latter, of the practices that have made fly agaric a difficult plant to write modestly about".

"Since the plant does not grow everywhere, for centuries there has been an active trade in it, especially between so-called 'Russians' and the far more primitive tribes that exist on the reindeer and inhabit one of the bleakest regions of the world. Treeless, frozen for months on end, the area near the Arctic Circle and adjoining Bering Strait is an unimaginably difficult place to sustain life. Here live, mostly in snow or mud huts, the Chukchee and Koryaks; here, because of the

scarcity of the plant and the large demand for it, the natives have hit upon the fact that muscarine is not destroyed in its passage through the kidneys, but is augmented in both quantity and effect by such passage. They have thus become urine-drinkers ".

CAAPI

Probably three million primitive natives within the drainage area of the upper Amazon use caapi, a woody vine (*Banisteria caapi*) which " contains a narcotic poison, banisterine, the effects of which are startling. They cut the lower part of the woody vine, macerate it in a wooden bowl under water, and when it is reduced to a pulpy mass the woody fiber is strained off, and enough water added to the remaining liquid to make it drinkable ". The beverage is imbibed as an excitant and narcotic, and is used ceremoniously in connection with the brutal whipping of young men, the yurupari ceremony, where caapi is part of the bloody ritual of the threshold of manhood.

KAVA

Kava is a mildly intoxicating beverage long used by the natives of the many widely scattered islands of the Southwest Pacific. It is prepared from a shrub, *Piper methysticum,* and owes its potency to a narcotic resin and a mild alcohol. " Its original method of preparation is idyllic. Only young girls and boys with clean teeth are ever permitted to make kava, for it involves chewing the lower part of the stem and the root of the plant that yields it. The boys and girls, sitting in a circle around a large wooden bowl, first wash their hands and wrists, rinse their mouths, then begin a rite which has been variously described as disgusting, simple, or natural, depending on how one looks at native customs. Actually the best kava is always made by chewing the pieces of root and stem. Neither the resin nor the starch is released in full flavor or efficacy until mixed with saliva, just as chicha-makers have found in the Andes. The bits of well chewed root and stem are spit into the bowl, which, like the finest teapots, is often a thing of great beauty. It is made of highly polished wood and is never washed. The residue of kava is allowed to dry, and years of accumulation leave the inside of the bowl with a beautiful sea-green patina. In Samoa the bowls may be as much as a yard in diameter, but in other islands usually smaller. Often they are beautifully carved ".

" Sufficient root is finally deposited in the bowl, while the drinkers sit patiently on their haunches. They must provide enough of a matrix to supply each with about half a coconut-shell of kava after water has been added. To remove the debris and strain the liquid, the natives use the fau, a picturesque strainer made from fringes of the stringy bark of the mahoe (*Hibiscus tiliaceus*). Its use is an art, as it must remove all particles and leave the liquid ready to drink ".

Originally drunk in connection with religious ceremonials, kava no longer has any ritual significance, and " on those islands controlled by England and France the chewing ceremony is forbidden on hygienic grounds, forcing the use of a metal grater which admittedly makes an inferior product ".

BETEL

" Over two hundred million people scattered all around the shores of the Indian Ocean, on all the islands of it, and stretching far to the eastward through the Dutch East Indies " chew the betel nut as a rather mild masticatory, but one which colors the saliva red and the teeth black; and some of its users are even fortunate enough to arrive at the condition known as ' toothstone ', which is caused by long accretions of the betel's limy residue. These, much prized and a badge of long addiction, protrude between the lips looking not unlike black tongues; in the Admiralty Islands they make one almost a chief.

" A vast population uses betel. Its source is cultivated in every garden, and in some places there are extensive plantations of the palm that yields the nut. This latter is a tall feather palm, variously called ' areca ', ' pan ', ' puwak ', and by the botanists *Areca catechu.* In Ceylon seventy-five thousand acres are devoted to the growing of over one hundred million trees, so great is the demand for the betel nut; each tree may produce only 200 to 250 fruits per year. The so-

called 'nuts' are actually the seed of the palm, about the size of a chestnut but enclosed in a fibrous husk which, with the seed inside, is about the size of a small egg. When ripe the nut is orange-yellow, and at that time it is sliced into thin strips, one or two of which are used with each chew. But these are never chewed by themselves, for it takes two adjuncts to bring out their best flavor, and, still more important, the effects that one seeks from betel".

"The first of these adjuncts are the small green or partially dried leaves of the vine *Piper betle,* variously known in the Indies as 'bulath', 'veth-thile', or even 'pan'—the latter, however, being more often applied to the palm. *Piper betle* is related to pepper (*Piper nigrum*) and cubeb (*Piper Cubeba*), but unlike either is a scrambling vine, the leaves of which must be picked fresh almost daily, . . . in the center of which the user puts a slice of betel nut. He then adds the third necessary ingredient, a pinch of lime about the size of a pea, rolls all in the leaf, and is then ready to chew".

"The effects are at first rather astringent, especially to the beginner, but this soon gives way to a very pleasant taste, which the more well-to-do increase by the addition of turmeric [rhizome of *Curcuma longa*] or cardamon [seeds of *Elettaria Cardamomum*]—luxuries denied to most betel chewers, who are among the poorest natives in the world. They chew it because it confers a sense of well being, is a mild stimulant, and, when fresh, is of a pleasant taste and odor. If narcotic at all, which seems unlikely, although the nut does contain the alkaloid arecoline, it is as a mild masticatory that betel has become so popular in the Far East".

CAFFEIN

Tea, coffee and chocolate, the world's foremost sources of this stimulating alkaloid, so far as beverages are concerned, are so well known as not to need extensive mention here. Less known, except to the natives of Amazonia, is guaraná (*Paullinia Cupana*), a woody climber of the South American jungle which "bears clusters of woody seeds the caffeine content of which is three times that of coffee. One still buys from the Indians near the ill-fated Ford rubber plantations sticks of guaraná, together with the file-like roof of the mouth of the piracacú, the largest fish in the Amazon. The sticks of guaraná look not unlike a chocolate-colored wooden sausage and are just as hard. The grater or file, devised by an Indian tribe that originally had no metal, is about six inches long, flat, and about an inch wide. It is just as serviceable as a nutmeg grater and is used the same way".

"The reason for this simple paraphernalia is the need of the natives for the caffeine of guaraná, and the impossibility of storing, or carrying in a canoe, the powdered seeds, because to do so would invite certain mildew in one of the rainiest regions in the world. Hence they powder the cured seeds, mix them with a coagulant, and make them up into the sausage-like form that one usually sees in the lower Amazon. When dry and hard they can be submerged or carried in a wet canoe for weeks until ready for use. Then the fish tongue is brought into play, grating off enough guaraná powder (about half a teaspoonful) to make a dose, which is always stirred into a cup of water and taken down while still in suspension".

BOOK REVIEWS

The Useful and Ornamental Plants in Zanzibar and Pemba. R. O. Williams. 497 pages; illustrated; obtainable from the Crown Agents for the Colonies, 4 Millbank, London, S. W. 1, or from the Government Printer, Zanzibar; 21 shillings. 1949.

The islands Zanzibar and Pemba constitute a sultanate and British protectorate of about 1,000 square miles off the coast of British East Africa. Some 800 native and introduced, wild and cultivated, plants of this area are alphabetically arranged and described in this volume, the first 95 pages of which include a brief botanical text and a listing of genera in more than 30 utilitarian categories. Ornamental plants are also listed under various headings.

Only cloves and coconuts are rated as major plantation crops in this island sultanate. The former, which are the dried unexpanded buds of clove trees (*Eugenia aromatica*), lead the agricultural exports from the islands and are the harvest from some four million trees on 50,000 acres. They "are used in cookery, in the preparation of cosmetics, perfumery and in Java for a particular brand of Eastern cigarette, and also to pin together the betel leaf (*Piper betle*) which contains the betel nut chew (*Areca catechu*). Clove stems are sold to the Clove Growers Association for the distillation of clove oil, the main constituent of which, eugenol, is used in medicine, microscopic work and largely for conversion into vanillin, a white crystalline product used for flavoring".

Coconuts (*Cocos nucifera*) are second to cloves among the agricultural exports, being shipped abroad principally as copra, secondarily as oil. Some four million bearing trees stand on about 57,000 acres. "There are small exports of coir and coir rope, and the residue oil cake from the coconut oil factories. The local method of preparing coir is to bury the dry coconut husks in the sandy beaches, weighted by rocks, in sites only exposed at low tide. After some months soaking, women beat out the fibre. This, when dried, is twisted by hand into rope. During the 1939–45 war large numbers of camouflage nets were manufactured for military purposes from coir fibre at Makunduchi, South Zanzibar".

Minor plantation crops consist of cacao (*Theobroma cacao*), cashew (*Anacardium occidentale*), coffee (*Coffea* spp.), chillies (*Capsicum* spp.), durian (*Durio zibethinus*), avocado (*Persea americana*), mango (*Mangifera indica*), orange (*Citrus* spp.), pineapple (*Ananas comosus*), sugar cane (*Saccharum officinarum*), tobacco (*Nicotiana tabacum*) and tuba (*Derris* spp.). Hundreds of other species are listed under cereals, vegetables, tubers, condiments, fruits, beverages, nuts, oil plants, timbers, fibers, medicinals, essential oils, dyes, tans and gums.

Corn and Corn Growing. Henry A. Wallace and Earl N. Bressman. Fifth edition by J. J. Newlin, Edgar Anderson and Earl N. Bressman. John Wiley & Sons. 424 pages; illustrated. 1949.

One of the outstanding examples of the highly practical results in agricultural practices that may evolve from purely theoretical investigation, originally pursued with no consideration for such matters, is the development of hybrid corn from the work in 1904–1907 by Dr. G. H. Shull at the Carnegie Institution for Experimental Evolution, Cold Spring Harbor, N. Y., and subsequent work by Dr. Donald Jones at the Connecticut Agricultural Experiment Station. While hybrid corn seed was first commercially produced in Connecticut in 1917, it was subsequently promoted in the Corn Belt by Henry A. Wallace, and today is the basis of a tremendous industry. This development and other findings called for a revision of Wallace and Bressman's well-known book, the latest edition of which covers in a very readable form practically every phase of corn, from its history and botany to the interrelationship between corn and hogs. It includes a list of human, livestock and industrial uses of corn and its byproducts that occupies 14 pages.

A Concise Encyclopedia of World Timbers. F. H. Titmuss. 156 pages. Philosophical Library, New York. 1949.

In the words that appear on the title page of this little book, it is "a useful work of reference for all users of timber containing detailed descriptions of nearly 200 different timbers, with macroscopic identifications of the woods in more common use".

The Wealth of India. Written by several contributors, published by the Council of Scientific and Industrial Research, 20 Pusa Road, Karolbagh, New Delhi, India. 1948.

Under the above major title with a subtitle reading "A Dictionary of Indian Raw Materials and Industrial Products", there was published in 1948 the first volume of what unquestionably will be one of the greatest assemblages of information on economically important plants and plant products that will have appeared in print. It is proposed that six volumes will eventually complete the set, constituting an encyclopedia of all economic products and industrial resources of India. About 90 percent of the 4,000 alphabetically arranged topics in the six volumes will deal with plants.

This monumental work, assembled by a number of Indian scholars, supersedes and immeasurably improves upon the classic works of George Watt who from 1889 to 1899 compiled his six-volume "Dictionary of the Economic Products of India" and in 1908 brought out "The Commercial Products of India", which was a condensed version of the larger work. The first volume of the new work is abundantly and excellently illustrated, is printed on coated stock, 8½″ × 11″, and is bound in deep blue rexine (art leather). It covers only the first two letters of the alphabet and is divided into two separately bound parts: Part I (Raw Materials) is listed at 24 shillings; Part II (Industrial Products) at 12 shillings.

There are only 21 animal and mineral topics in the first volume, while the vegetable kingdom is so well covered in 219 articles that every student of plant utilization will be induced by them to wish that comparable reference works on the economic plants of other countries were also available. The principal botanical articles in this first volume, with the number of pages devoted to them, concern the botany, history, production, harvesting, processing, utilization and trade in products derived from the following genera:

Acacia (16): gum, tannin, timber
Aleurites (3): Chinese wood oil, Japanese wood oil, tung oil
Anacardium (4): cashew apple, cashew nuts, shell oil
Arachis (19): peanuts, peanut oil, peanut protein
Areca (4): betel nuts
Artocarpus (3): bread fruit, Jack fruit
Bamboos (10): construction work, seeds and shoots for food, paper pulp
Borassus (4): edible seed, fruit made into toddy, bassine fiber from leaf stalks
Brassica (15): vegetable crops, oil-seed crops

American Heartwood. Donald Culross Peattie. Houghton Mifflin Co. 307 pages. 1949. $3.50.

The facile pen of this well-known writer of non-technical and very readable books has provided in this volume an account of American history from the time of the Norsemen to the opening of the West against a background of the trees which those pioneers encountered and utilized in countless ways. While the volume deals primarily with people and touches only upon scattered and selected incidents in American history, it does contain some specific references that are of interest to readers of this periodical. In the first chapter, for instance, one reads about the repeated visits of the Norsemen to the North American continent a century or two before and after the year 1000 and of their returning to Europe with "mösurr" wood for use at home. The term means "gnarled wood", but the identity of the wood has never been determined, though it has been attributed at various times to bird's-eye maple, canoe birch, white oak and sycamore. Centuries later Alvar Muñez Cabeza de Vaca, in the early sixteenth century, extensively explored what is now Texas and left the first descriptions of pecan and yaupon, a native holly, the leaves of which were brewed into a tea by the Indians and are still so used to some extent in the South. Captain John Smith of Jamestown fame sent sassafras and logs of

cedar and pine to England, and in subsequent days the colonists discovered other uses for the native woods. "Thus our ancestors taught us—and we have never improved on the method—to fit seasoned hickory dowels into chair seats of green sugar maple. When the maple shrinks it clasps the hickory leg in a grip that nothing can loosen ".

Of the famous frigate " Constitution ", Mr. Peattie tells us: " For her decks, they cut the pitch pine of South Carolina and for the gun floor solid white oak of Massachusetts; red cedar and tough black locust went into her beams. The Carolinas yielded pitch from their longleaf pines. White oak of New Jersey built her keel. And last, for her masts, they cut three towering, toppling white pines of Maine, arrow-straight, peeled like a swift runner, all of a clean-limbed piece."

And in the post-Revolutionary history we read about the rived oak shakes for roofs and roof poles of ash, furniture of black walnut tied with cords of elm rope, buckeye as the favorite wood for whittling, red birch for pegs to hang clothes on and white ash for the johnnycake boards. Thus the pioneer in the great American wilderness fashioned his home for his wife from the trees that grew about him.

" But of all the trees in the wood, hickory served him best. Hickory made the new helve to his axe; it made a ramrod for his gun. When he laid her a pencheon floor to the cabin, of hackberry, it was out of broom hickory splits that he fashioned a broom for her sweeping. . . . Peeled to the naked wood, hickory made his planting sticks, and wythes of it made hoops and even cordage. . . . Hickory threw out the greatest heat upon the hearth, dropped the sweetest, toughest nuts in all the forest, made the strongest wheels, and the sturdiest lap rings and wagon poles ".

The Coming Age of Wood. Egon Glesinger. 279 pages. Simon and Schuster, Inc. 1949.

In this volume the Chief of the Forest Products Branch of the Food and Agriculture Organization of the United Nations has provided a very informative and extremely readable account of wood and its byproducts in a world of diminishing natural resources. Not only are the technological achievements in this field of utilization lucidly described, but, perhaps more important, their significance in world economy and not merely as commercial enterprises is poignantly emphasized. The first nine chapters are devoted not only to general information concerning wood, but also to the role it plays in the life of nations and the measures that must be taken to maintain and extend that role. A warning is given to the United States where waste of natural resources has been appallingly great, and a blueprint for perpetuating the resources of the forest is presented.

The last nine chapters are concerned with the specific products that have already been commercially obtained from wood, wholly apart from lumber, but which have not been developed in any manner worthy of their importance. There is, for instance, wood sugar, obtained either by hydrolysis of sawdust and other sawmill waste through acid treatment or in the waste sulphite liquors of the paper pulp industry. These sugars, for there is more than one kind obtainable in this way, offer an enormous reservoir of raw material for fermentation into alcohol for industrial utilization and into fodder. From the byproduct sugars of the pulping industry alone, 200 to 300 million gallons of alcohol and from five to six million tons of alcohol-derived end products can be put on the market. In 1942 the pulp mills of Sweden produced 500,000 tons of fodder cellulose in this manner, and aquavit, Scandinavia's favorite drink, is a product of the sugars derived from wood.

Rayon and other possible cellulose products of wood receive their share of attention in this volume, as well as synthetic vanillin from the enormous quantities of lignin wasted along with the sugars in pulp mill waste liquors.

Sixty different chemicals are extractable from pyroligneous acid, the liquor condensate of charcoal vapors. Most important among them are acetic acid and methanol, that have acquired key positions in modern industrial chemistry. Destructive distillation of wood is another source of chemicals, especially in wood tar, but it is an industry that has been on the decline as a result of other more lucrative sources, such as coal and petroleum. And finally there is wood gas which has

fueled hundreds of thousands of machines in Europe.

Each of the foregoing products, and others not mentioned here, offers fields of wood utilization, as yet undeveloped because of both technological and economic factors, that would go far toward reducing the present shameful waste of timber and toward yielding additional revenue for those who successfully develop them. It is because of the role which their proper integration plays in at least partially meeting the problem of diminishing natural resources, that everyone interested in, or at least cognizant of, this problem should read Dr. Glesinger's book.

Genetics in Swedish Forestry Practice. Bertil Lindquist. 173 pages; illustrated; Svenska Sgoksvårds föreningens, Förlag. Stockholm, Sweden. The Chronica Botanica Co., Waltham, Mass., U.S.A. 1949. $3.50.

This excellent little book offers the reader an account of how the findings in the field of forest tree genetics can and should be applied in silviculture by the practicing forester.

The basic ideas brought forward by Prof. Lindquist are not new to the American forester. We know the importance of provenience of forest trees; we know that only well-formed trees should be left as seed trees; but how often is this knowledge actually used when it comes to the collection of seed or the establishment of reproduction? The common excuse is that one cannot afford to leave the best of the crop for seed trees, or that when you have to produce 20 million seedlings yearly in the nursery you have to compromise and take your seed where you can get it. To this is added a remark expressing a doubt that quality and quantity actually are inherited in trees.

The book shows how dangerous such an attitude can be. Drawing his proofs from Danish, German and other European experiments, Lindquist concludes that the present poor quality of the timber around old Swedish settlements, and in densely populated areas, is due largely to the cutting to a diameter limit, and cutting of quality logs which leaves only poor trees to take care of reproduction.

With regard to seed collection, the writer states that " collection without consideration of choice of mother tree and collection areas involves a very serious risk of getting seed with bad hereditary properties, and of poor timber production in the future ".

Lindquist proceeds to give a thorough description of the work which now is being carried out in Sweden. The pine stands are being classified with seed collection in mind, the immediate goal being that seed be collected only within the " provenience zones " in so-called " plus stands ", or, if enough seed cannot be obtained here, at least from better " normal stands "; collection in " minus stands " should be completely abolished.

But the Swedes do not stop here. The entire country is being searched for the very best individuals of the different species, the so-called élite trees. Plans are being drawn up for the establishment of " seed plantations " throughout the country. In such plantations five or six clones of the élite trees are planted in mixture, and it will be possible to harvest the very best seeds which nature provides in such stands.

One large section of the book deals with the " requirements for élite status " for the important timber species. Although such requirements depend to a large extent on the market conditions and therefore cannot be transferred from one country to another, they are still of much interest to the American forester as a guide in setting up similar standards in this country.

Probably the most interesting section of the book considers the economic aspects of the plan. Prof. Lindquist's conclusions are very encouraging. Not only will the seed from " seed plantations " give higher yields of better quality, but also a shortening of the rotation is likely to result, and fewer plants need be planted per acre, *etc.*, all factors which would more than counterbalance the necessary higher cost of the improved seed.

The book is written for the practising forester, to show how genetics can be applied in routine work. No complete description of the tree-breeding work in Sweden is intended or attempted; it is the silvicultural consequences of the latest genetical work which are discussed. As such it is an inspiring book which demands the attention of all foresters in the United States.—HANS NIENSTAEDT, *Connecticut Agricultural Experiment Station, New Haven, Connecticut.*